SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Liming Digesters—Sawyer et al.

Synthetic Detergents Determination—Edwards and Ginn

Submerged Sludge Heating—Baxter and Horlacher

Blast Furnace Wastes Guide—Black et al.

Animal Parasites in Sewage—Wang and Dunlop

AUGUST, 1954—VOL. 26, No. 8

Make Plans to Attend

27TH ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

OHIO SEWAGE AND INDUSTRIAL WASTES TREATMENT CONFERENCE

NETHERLAND PLAZA HOTEL
CINCINNATI, OHIO

October 11-14, 1954

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS
325 ILLINOIS BUILDING CHAMPAIGN, ILLINOIS

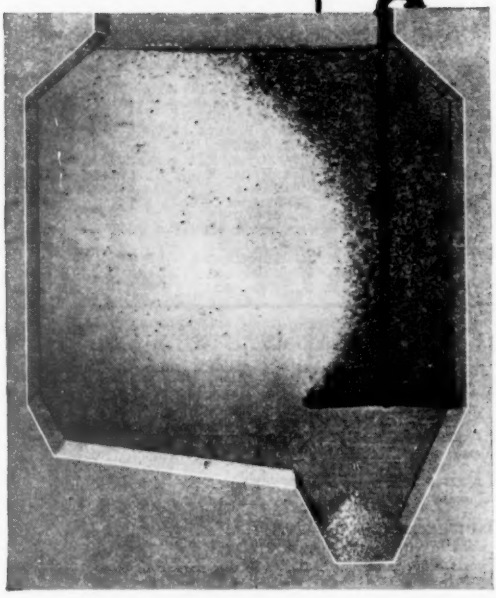
AER-DEGRITTER*

- Positive Grit Removal and Washing
- Air Controlled Settling Velocities Independent of Flow

Here's the grit removal system that gives you superior performance *plus* the advantage of low installation and maintenance costs. Only a simple structure is required—grit is cleaned so thoroughly that separate washing tanks are not required. Because there is no mechanical equipment that can be clogged by coarse sewage matter, the Aer-Degritter* can be located ahead of all pumps and other mechanical equipment. Tests made on grit removal by Aer-Degritters* have consistently shown *less* than 0.05% putrescibles. Easy-to-clean Swing Diffusers and Precision Tubes permit easy access to the grit hopper, and allows cleaning without taking the tank out of service.

Extremely flexible in operation, the Aer-Degritter* can maintain proper settling velocities regardless of the rate of sewage flow.

CHICAGO SEWAGE EQUIPMENT



The Aer-Degritter* diffuses air into the grit tank to control sewage velocities at the bottom of the tank, allowing grit to settle out *without organics*. This principle of air controlled velocities was first demonstrated in sewage treatment plants designed by the office of Charles H. Hurd, Consulting Engineer. The Hurd method was an improvement over the then practiced means of controlling grit tank velocities. The Aer-Degritter* is, in turn, an improvement on the Hurd method.

OVER 60 AER-DEGRITTERS IN OPERATION IN LARGE AND SMALL PLANTS

Aer-Degritter* Systems may be installed in existing structures at the head end of pre-aeration and grease removal tanks. Other applications include use in wet wells of lift stations for grit and odor removal and in power plant and waterworks intakes.

*The application of the equipment, as well as the equipment itself is covered by U.S. Patents No. 2,532,457, No. 2,144,385, No. 2,328,655 and No. 2,555,201.

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SEWAGE EQUIPMENT DIVISION

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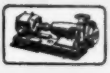

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SEWAGE AND INDUSTRIAL WASTES

REG. U. S. PAT. OFF.

A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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Model DVS manually controlled Chlorinizer installed at Estacada, Oregon — Supt. Glen Ebert at left, Mayor Ford A. Darrow, at right.

CHLORINIZER Made a Big Difference in the Small Town of Estacada, Oregon

For the 1,000 people of Estacada, this Builders Model DVS Chlorinizer represents an important municipal economy. Previously another type of equipment had cost up to $10.00 a month in heating bills alone to overcome a serious "chlorine ice" problem. With the Chlorinizer, safe and dependable chlorination has been maintained even when water temperature dropped to 33°F. and air temperature stood at 17°F. . . . further proof of the advantage of metering and controlling chlorine gas in the dry, inert state.

Since early 1953 when the installation was made, the Chlorinizer has been in service continuously, and has required almost no maintenance. In a town of this size, municipal budgets cannot afford specially trained chlorination maintenance men. The Chlorinizer has operated since installation completely without need for specialized personnel

More and more, the trend is to Chlorinizer, for new projects, for replacement, for plant expansion. Find out for yourself why this safe, simple, dependable chlorine gas feeder will save you money and serve you well. Write for descriptive Bulletins. Builders-Providence, Inc., 368 Harris Avenue, Providence 1, Rhode Island.

Mayor Ford A. Darrow of Estacada, Oregon states, "We had considerable trouble with another make . . . and to date have had no trouble with Chlorinizer. We are entirely satisfied and would recommend this chlorine gas feeder".

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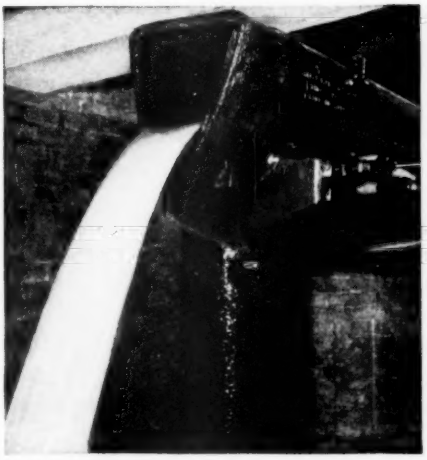

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Simplex Type S Parabolic Flume was designed specifically to master *all* of these problems . . . accurately measures free-flowing wastes or sewage over a FULL 20 to 1 flow range!

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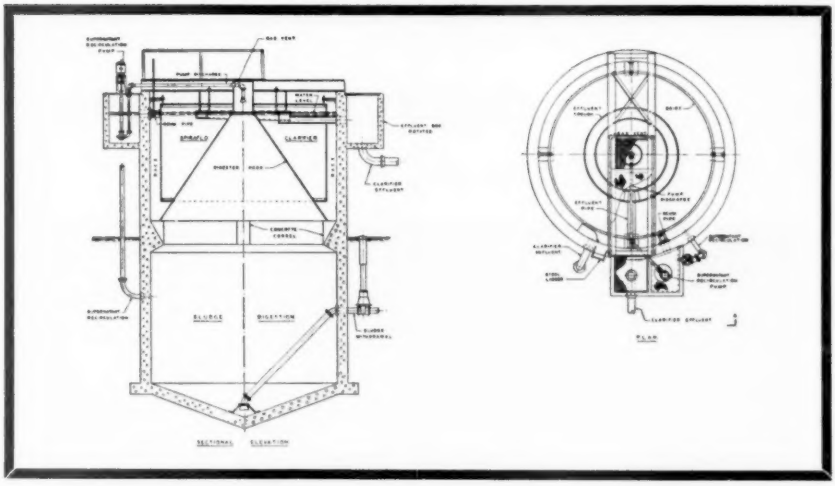
Association	*Place*	*Time*
Pennsylvania Sewage and Industrial Wastes Assn.	The Pennsylvania State College, State College, Pa.	Aug. 25–27, 1954
Iowa Sewage Works Assn.	Hotel Russell-Lampson, Waterloo, Iowa	Sept. 14–16, 1954
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Andrew Jackson Hotel, Nashville, Tenn.	Sept. 20–22, 1954
North Dakota Water and Sewage Works Conf.	Hotel Dakota, Grand Forks, N. D.	Sept. 22–24, 1954
Georgia Water and Sewage Assn.	Georgia Institute of Technology, Atlanta, Ga.	Sept. 22–24, 1954
Missouri Water and Sewage Conf.	Hotel Governor Jefferson City, Mo.	Sept. 26–28, 1954
South Dakota Water and Sewage Works Conf.	Lawler Hotel Mitchell, So. Dak.	Sept. 28–30, 1954

TWENTY-SEVENTH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
in conjunction with
Ohio Sewage and Industrial Wastes Treatment Conference
Netherland Plaza Hotel, Cincinnati, Ohio
October 11–14, 1954

Pacific Northwest Sewage and Industrial Wastes Assn.	Hotel Eugene Eugene, Oregon	Oct. 21–23, 1954
Canadian Institute on Sewage and Sanitation	Windsor Hotel Montreal, P. Q. Can.	Oct. 25–27, 1954
New England Sewage and Industrial Wastes Assn.	Hotel Stratfield, Bridgeport, Conn.	Oct. 28, 1954
Rocky Mountain Sewage Works Assn.	Broadmoor Hotel, Colorado Springs, Colo.	Nov. 8–10, 1954
Florida Sewage and Industrial Wastes Assn.	Sorrento Hotel, St. Petersburg, Fla.	Nov. 8–10, 1954
North Carolina Sewage and Industrial Wastes Assn.	George Vanderbilt Hotel, Asheville, N. C.	Nov. 8–10, 1954
West Virginia Sewage and Industrial Wastes Assn.	Hotel Prichard, Huntington, West Va.	Nov. 9–10, 1954
Nebraska Sewage and Industrial Wastes Assn.	Keystone Hotel, McCook, Nebraska	Nov. 11–12, 1954
Oklahoma Water, Sewage and Industrial Wastes Conf.	Student Union Bldg., Stillwater, Okla.	Nov. 15–20, 1954



It's the HEART
of "package" treatment systems
for small communities —
The **SPIRAGESTER**

This compact unit, designed especially and specifically for small sewage treatment plants, performs the functions of primary clarification and sludge digestion: the Spiragester by Yeomans. It is recommended as the "heart" of all trickling filter systems for small treatment plants.

Solids removal is accomplished in the upper portion of the Spiragester by spiral downward flow of the influent. The sewage then spirals upward in regulated uniform flow for final maximum removal of settleable solids, and for entry into effluent weir troughs. Solids are collected in the lower digestion portion of the tank and are attacked by organisms which render it inoffensive and ready for removal.

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- Tailored to job—not cut-down versions of a big plant
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- Guaranteed satisfaction—backed by Yeomans engineering experience and reputation

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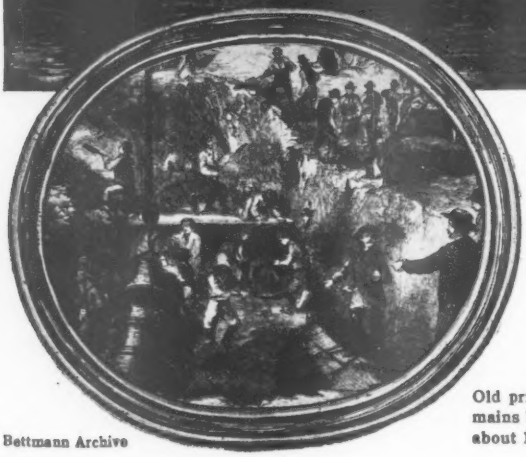
This is New York, as seen from East River, showing Empire State, Chrysler and United Nations buildings.



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Old print showing cast iron water mains being installed in New York about 100 years ago.

MODERNIZED **cast iron**

# of EXPERIENCE... they must be right!

NEW YORK installed cast iron water mains 100 years ago... and installs them today!

One hundred years ago, New York was a city of about 750,000 population, served by 237 miles of water mains. Today's eight million population requires 5500 miles of mains, of which 98% are cast iron. Some of these mains are still functioning after a century and more of service. From 90 M.G.D. a century ago, capacity has grown to 1500 M.G.D.

In good condition after 100 years of service, this cast iron distribution main is one of several still functioning in New York City.

A customer who buys your product year after year—generation after generation—is a "jewel beyond price". Be you merchant or manufacturer, you might count such customers on the fingers of your two hands. Yet, the cast iron pressure pipe industry can count more than 60 of them—utilities that have been buying cast iron pipe for water or gas mains (or both) for 100 years.

Cast iron pipe has been a rugged, long-lived product from the earliest days. Today's *modernized* cast iron pipe, centrifugally cast, is even stronger, tougher, and more uniform in quality. And, where needed and specified, it is centrifugally lined with cement mortar to assure sustained carrying capacity throughout the long life of the pipe.

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CAST Q IRON

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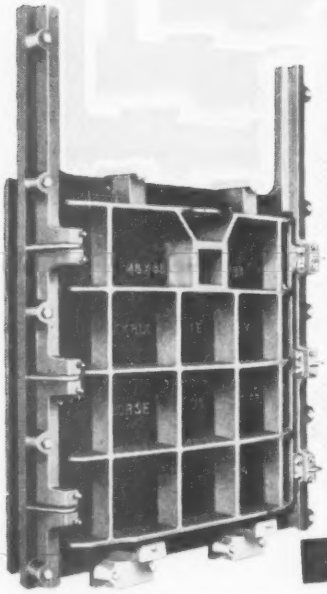
pipe FOR MODERN WATER WORKS OPERATION

Pekrul *Grows*



To keep pace with the ever increasing demand for PEKRUL GATES over half a century, MORSE BROS. MACHINERY has just completed an extensive modernization program. The installation of many new machines and facilities, an increased engineering staff, and complete, new, custom re-tooling specifically for PEKRUL GATE production means...

modern design and superior engineering service...

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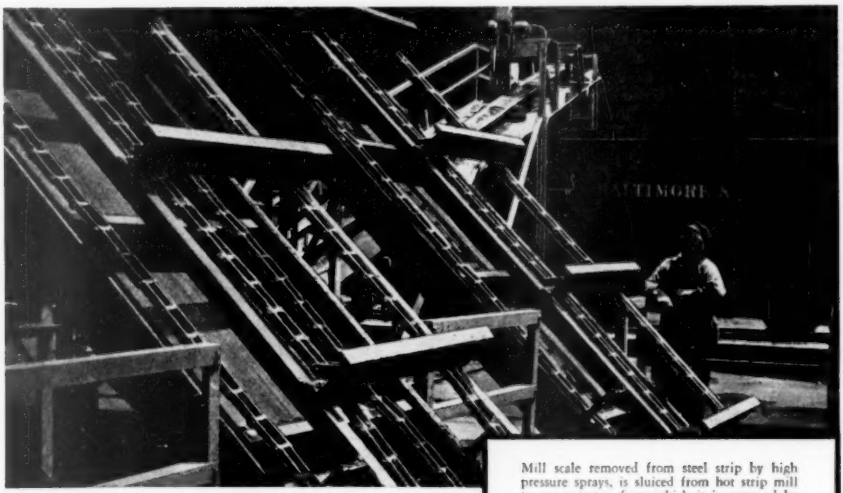
Boosts mill scale recovery from 250 to 475 tons a week



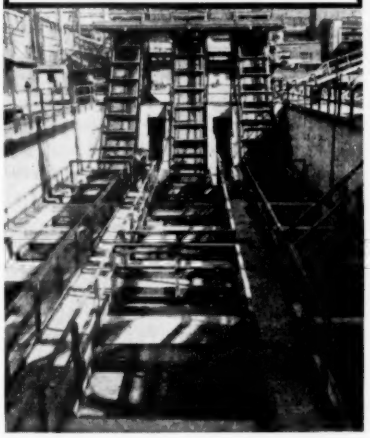
Mill scale removed from steel strip by high pressure sprays, is sluiced from hot strip mill to concentrator, from which it is removed by three Link-Belt Straightline Collectors. Two Link-Belt belt conveyors—a horizontal collecting belt and an inclined pivoted loader—then carry scale to railroad cars. After fusing by sintering, the recovered scale is charged into blast furnace.

Steel mill also eliminates clogged sewers with LINK-BELT Straightline Collectors

HERE'S the case of a mill that saw its profits literally "going down the drain"—and did something about it. Before installing Link-Belt Straightline Collectors, almost half the scale passed into the sewers, causing frequent clogging.

Now, with their new collectors, they've boosted recovery from 250 to 475 tons a week. Since the scale is 72% pure iron, each ton is equivalent to 1½ tons of ore. And the waste water is actually clearer than the river water . . . aiding the anti-river-pollution program.

No matter what your waste treatment problem, you'll find it pays to call in a Link-Belt engineer. Drawing on Link-Belt's broad experience in this highly specialized field, he can recommend the equipment best suited to your requirements from the complete Link-Belt line. Ask your Link-Belt office for further information.



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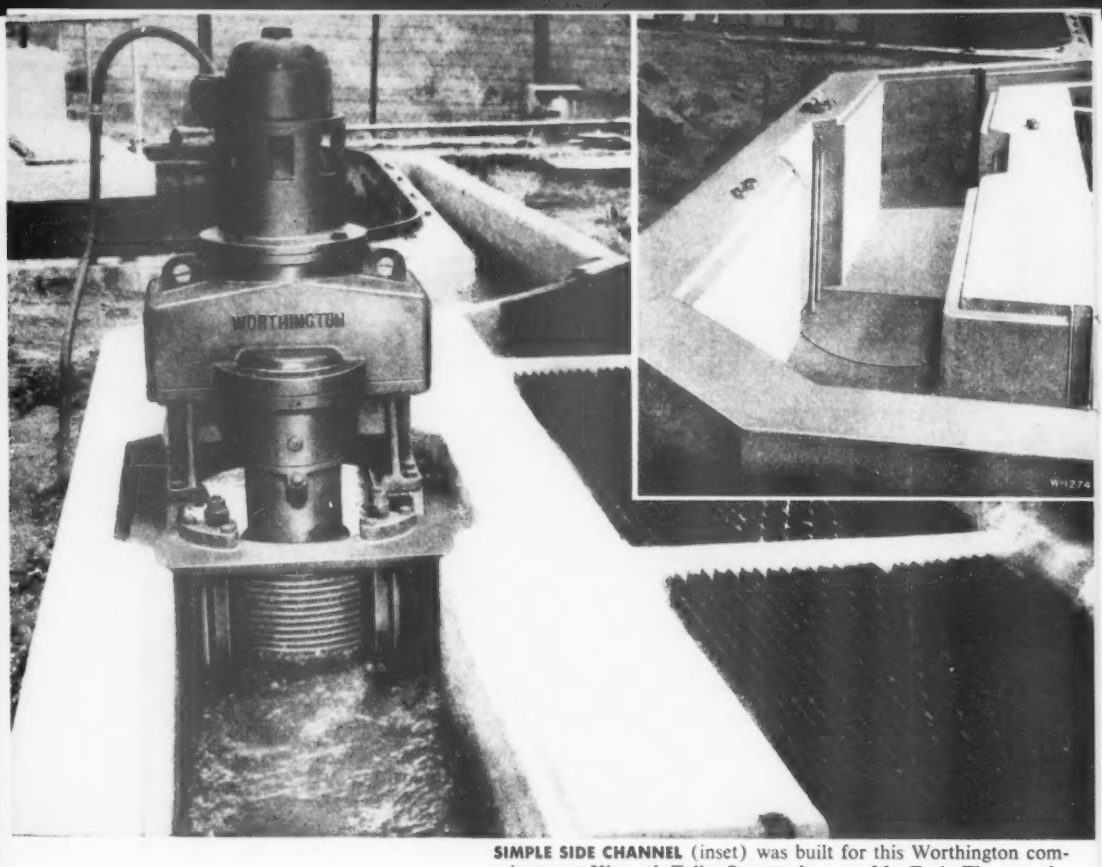
LINK-BELT COMPANY: Plants: Chicago, Indianapolis, Philadelphia, Colmar, Pa., Atlanta, Houston, Minneapolis, San Francisco, Los Angeles, Seattle, Toronto, Springs (South Africa), Sydney (Australia). Sales Offices in Principal Cities. 73.094



SIMPLE SIDE CHANNEL (inset) was built for this Worthington comminutor at Klamath Falls, Oregon, because Mr. E. A. Thomas, the City Engineer, wanted to use the existing channel as a by-pass.

Low installation cost swings Klamath Falls to Worthington

Since the Worthington comminutor is designed so that raw sewage flows straight through its screen, it's easily installed in a straight rectangular sewage channel.

Result? Expensive masonry work is not needed, which makes for simplified, low-cost installation.

This was an important factor in the selection of a Worthington 25C6 comminutor as part of recent improvements at the Klamath Falls, Oregon, Sewage Treatment Plant.

This comminutor, installed downstream from a grit chamber and upstream from a clarifier, was lifted directly from its packing crate and set right in the channel in a minimum of time.

Easy-to-remove cutter racks for occasional sharpening and the built-in flood protection provided by a mercury seal are other advantages of the Worthington comminutor.

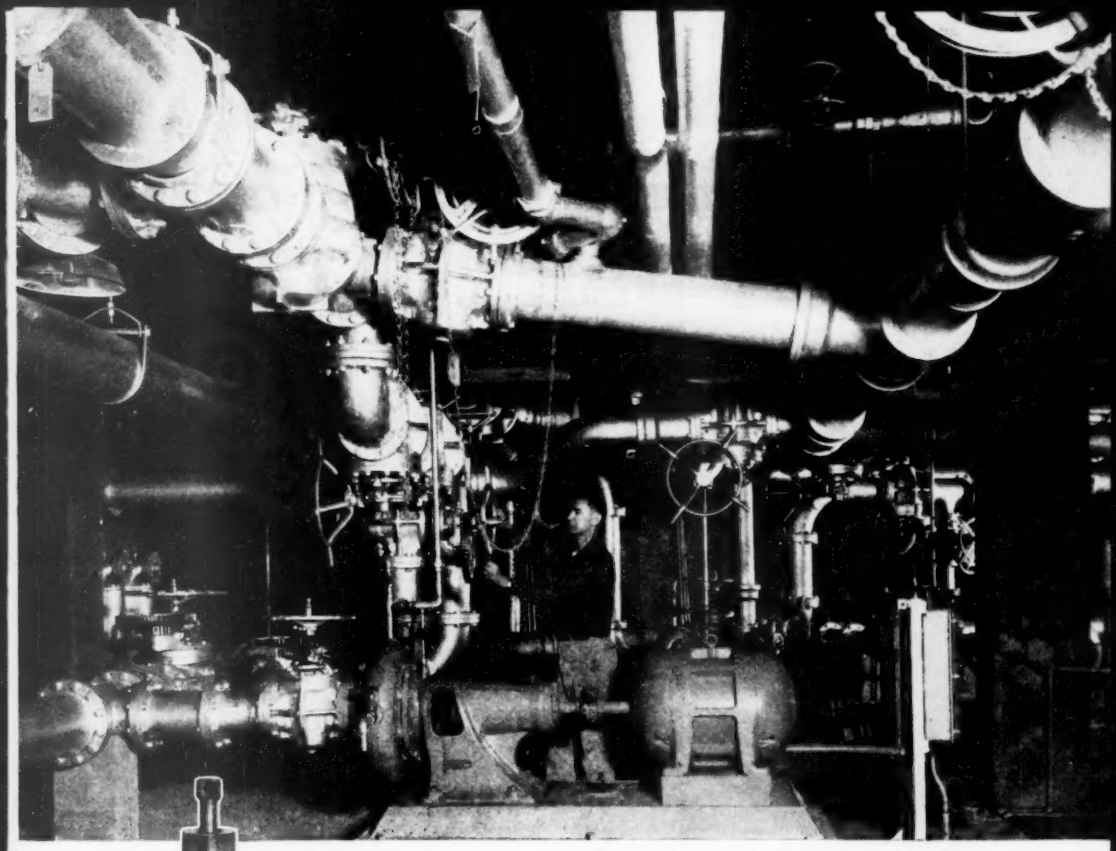
Get all the facts and figures on the rugged Worthington comminutor. Check with your nearest Worthington district office. Or write today for new engineering manual on comminutors, W-317-B17. Worthington Corporation, Public Works Division, Harrison, N.J.

W.4.5

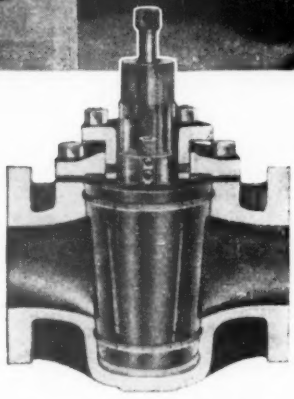
WORTHINGTON

ALL MAJOR PUBLIC WORKS EQUIPMENT UNDER ONE RESPONSIBILITY

Water Works Pumps • Sewage Pumps • Comminutors • Vertical Turbine Pumps • Vacuum Pump



Does this look like a lot of valves on one unit? See copy below.



Cutaway view of a Rockwell-Nordstrom valve showing the grooves which carry lubricant to all areas of the seating surface.

ROCKWELL-
Nordstrom
VALVES

Lubricant-Sealed for Positive Shut-Off

ANOTHER ROCKWELL PRODUCT

The Answer to Sewage Valve Problems . . . STANDARDIZE ON ROCKWELL-NORDSTROMS

This photograph shows Rockwell-Nordstrom gear-operated valves on digester feed lines to the sludge withdrawal pumps in a Midwest sewage treatment plant. There are approximately 100 such valves on this unit alone. But whether they are installed on sludge lines, water lines or sewage gas lines, Rockwell-Nordstrom valves out-perform and outlast any other type.

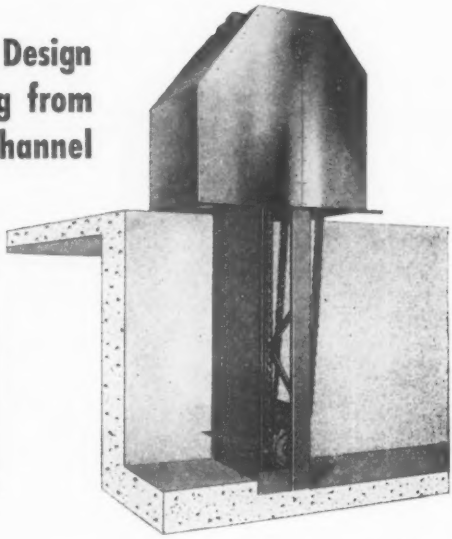
Rockwell-Nordstrom valves are built on an entirely different principle than most valves. Instead of a metal-to-metal closure, a film of pressurized lubricant surrounds the seat ports preventing flow of the line fluid around the plug. This lubricant keeps the valve ready to operate easily with a quick quarter turn, too. In addition, the vital seating area is protected from corrosion because *it is never exposed to the line fluid.*

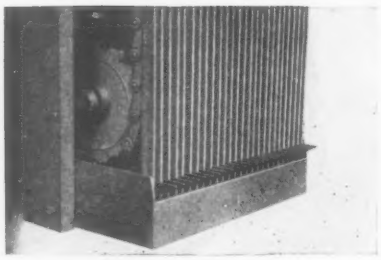
End your sewage valve problems by standardizing on the best valves for sewage treatment services—Rockwell-Nordstrom lubricant-sealed valves. Rockwell Manufacturing Company, Pittsburgh 8, Pa. Canadian Licensee: Peacock Brothers, Limited.

COMPLETELY AUTOMATIC MECHANICALLY CLEANED

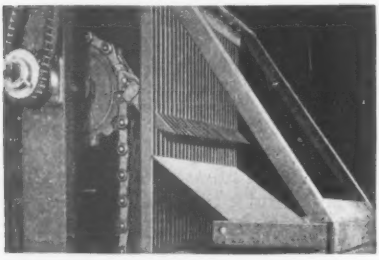
UNIT BAR SCREEN

Exclusive Pivoted Rake Design Assures Positive Raking from Absolute Bottom of Channel





Horizontal position of rake teeth at the beginning of cleaning cycle accomplishes raking from absolute bottom of channel. Gets under and picks up all screenings—does not push them away • Note unobstructed channel approach.



Rake making 45° radial drop to discharge screenings into trough—Note shear pin hub with tool steel shaft and hub inserts for perfect shear action.

THE "AMERICAN" UNIT SCREEN

Completely automatic with a limit switch which stops operation with the rake out of the flow when time control or water level control cycles have been completed • Easily installed as a unit in concrete channels • Total height of unit from mounting floor to motor base is only five feet • The entire above-floor structure is enclosed with stainless steel panels secured by quick opening fasteners to permit easy inspection and access.

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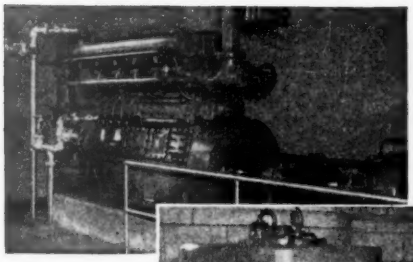
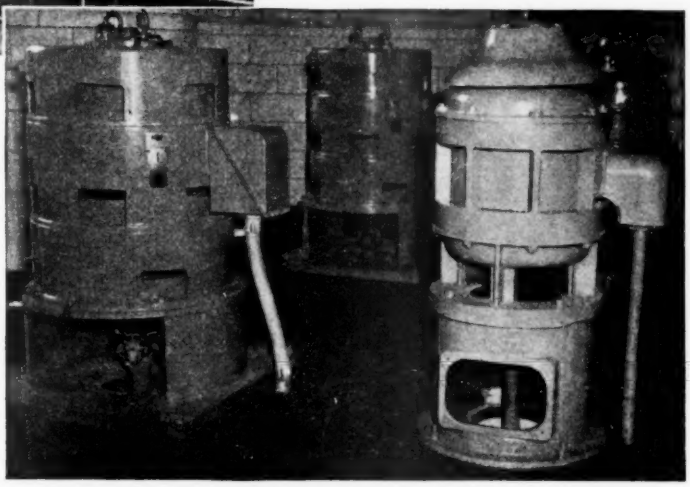
INERTOL® PAINTS

specified in Elmira, New York, plant



Sparkling protection was afforded this big gas engine at Elmira's Sewage Treatment Plant with Inertol Glamortex® Enamel. All surfaces were first primed with Inertol Quick-Drying Primer No. 626, a top-quality rust inhibitor which provides a perfect bond for the finish coats.

Easy maintenance of this battery of sludge pump motors was achieved with Glamortex Enamel, Battleship Grey No. 331. This easy-to-clean paint stands up for years under abrasion, oil spillage and frequent cleaning.



Inertol Paints meet precise requirement of plant designed by Nussbaumer, Clarke & Velzy

For top protection, Elmira's Sewage Treatment Plant needed paints that would provide lasting durability, elasticity and chemical resistance. That's why Inertol coatings were chosen for this modern plant which was designed and constructed under the supervision of Nussbaumer, Clarke & Velzy. Inertol meets all these exacting requirements. For 18 years, the city of Elmira has been using hundreds of gallons of Inertol Paints—bituminous coatings as well as colored enamels.

All over America, thousands of Inertol-painted installations speak for this paint's economical and efficient superiority. Whatever your specific painting problem is, there's sure to be an Inertol coating to solve it. Ask to have your local Inertol Field Technician call. Or write for our free "Painting Guide." It's prepared especially for Consulting Engineers, Specification Writers, Design Engineers and Plant Superintendents. Send for this valuable booklet today.

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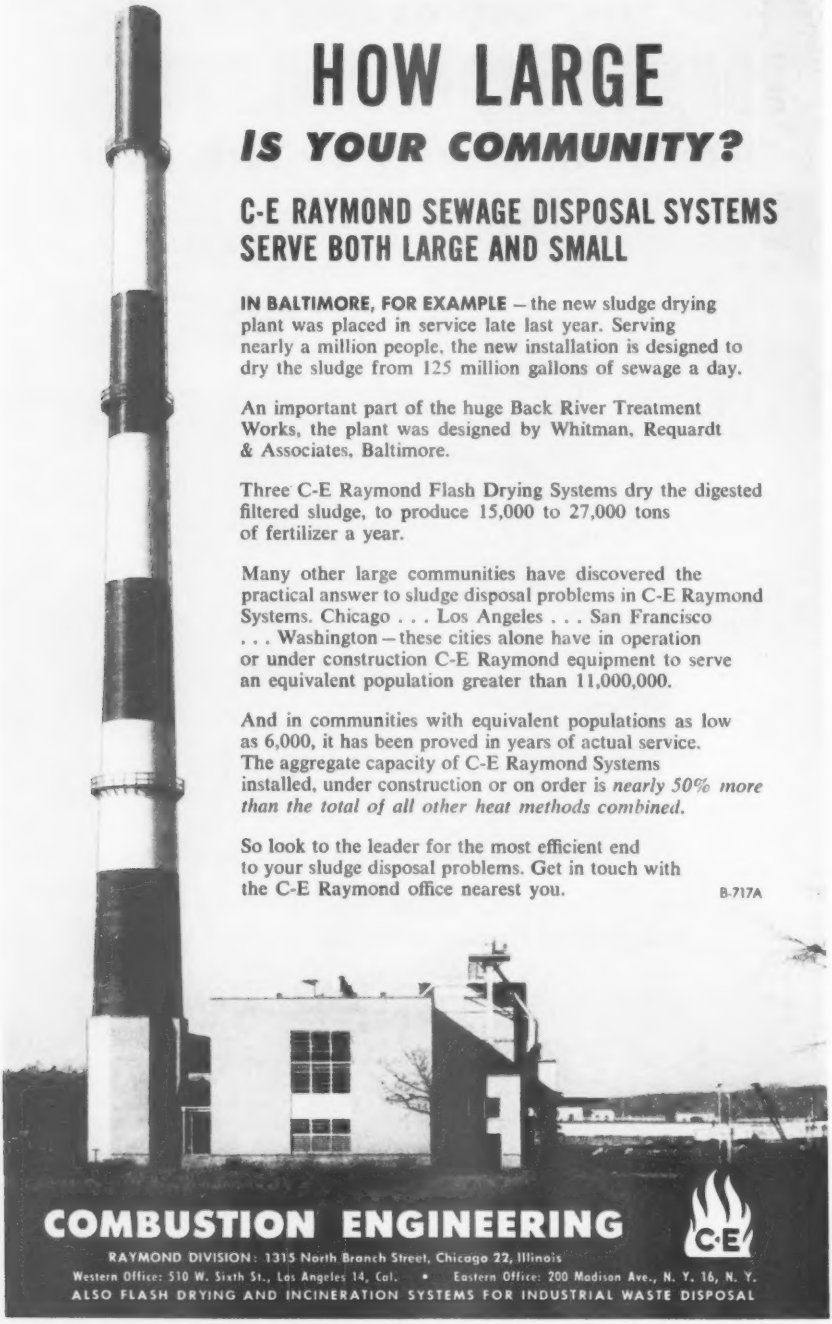

HOW LARGE
IS YOUR COMMUNITY?

C-E RAYMOND SEWAGE DISPOSAL SYSTEMS SERVE BOTH LARGE AND SMALL

IN BALTIMORE, FOR EXAMPLE – the new sludge drying plant was placed in service late last year. Serving nearly a million people, the new installation is designed to dry the sludge from 125 million gallons of sewage a day.

An important part of the huge Back River Treatment Works, the plant was designed by Whitman, Requardt & Associates, Baltimore.

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Many other large communities have discovered the practical answer to sludge disposal problems in C-E Raymond Systems. Chicago . . . Los Angeles . . . San Francisco . . . Washington – these cities alone have in operation or under construction C-E Raymond equipment to serve an equivalent population greater than 11,000,000.

And in communities with equivalent populations as low as 6,000, it has been proved in years of actual service. The aggregate capacity of C-E Raymond Systems installed, under construction or on order is *nearly 50% more than the total of all other heat methods combined.*

So look to the leader for the most efficient end to your sludge disposal problems. Get in touch with the C-E Raymond office nearest you. B-717A

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in the design of

industrial waste problems

INFILCO's experience in solving industrial waste disposal problems through the application of activated sludge equipment is available to you today, at no obligation. Write for details.

BIOLOGICAL TREATMENT OF INDUSTRIAL WASTES with activated sludge is not new with INFILCO, an organization long considered a leader in the development of activated sludge processes and equipment.

Many installations treating vegetable canning, refinery, pulp, paper and a variety of other organic wastes, are in successful operation because INFILCO pioneered methods and equipment to adapt activated sludge treatment to the needs of industry's ever-increasing waste problem.

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INFILCO INC. *Tucson, Arizona*

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Two Bests

1
WASTE DISPOSAL BY INCINERATION

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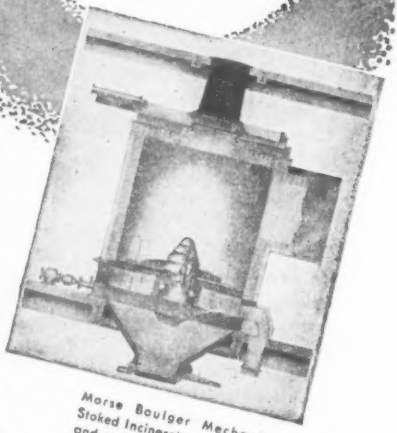
Select from this list of five different types and you will get the best type for your particular problem whether it is trash, garbage, sewage sludge, institutional organic matter . . . separately or in combination.

- For Garbage and Rubbish
  - (1) Cell and Hearth
  - (2) Circular Hearth and Grates — Mechanically Stoked
- For Sewage Sludge Drying and/or Burning
  - (3) Multiple Zone Furnace—Mechanically Stoked
- For Garbage, Rubbish and Sewage Sludge
  - (4) Circular Unit, Mechanically Stoked, with Separate Compartment for Sewage Sludge Reduction
- For Garbage and Trash (Individual Buildings)
  - (5) Kernerators (Flue-Fed and Ready-Built)

Our incinerator experience goes back nearly sixty years. Our work is guaranteed. Our incinerators are constructed under the supervision of our own field men who stay with it until the unit is in operation, fully broken in and crews instructed.

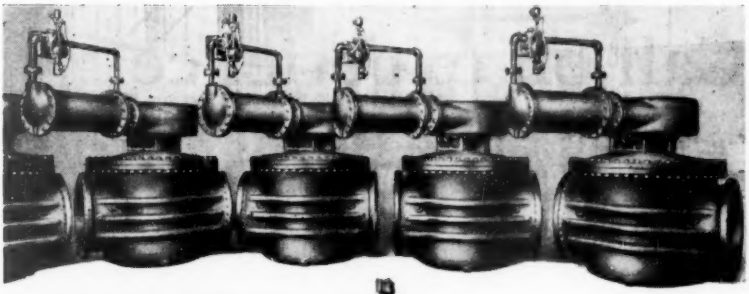


Morse Boulger Mechanically Stoked Incinerator, circular hearth and grate, for garbage, rubbish and all kinds of industrial wastes.

MORSE BOULGER DESTRUCTOR CO.

205-S East 42nd St. New York 17, N. Y.

Representatives in Principal Cities



36" CONE VALVES

with clear opening

To supplement its hydroelectric power, TVA has built a series of steam plants on the Tennessee and Ohio rivers. These new units will furnish power required for Atomic Energy and other projects.

In this vital program, 52 Chapman Automatic Cone Valves were utilized for these plants . . . to act as check valves on the condenser water pumps. Each of these valves weighs approximately 11 tons.

Chapman designs and builds these valves in a range of sizes from 6" to 48" for check, throttling, pressure reduction and stop valve service. This is only one of many special Chapman valves. Remember, there's no problem in flow control that's too big or too tough for Chapman.

That's why it saves time and money to *check with Chapman first, every time.*

The **CHAPMAN VALVE**
Manufacturing Company
Indian Orchard, Mass.

Call on experience

Sixty five years of practical experience in the design, manufacture and installation of thousands of multiple hearth furnaces is at your call.

The modern Nichols Herreshoff sewage sludge dryer-incinerator, providing dependable, economical, dual-purpose sludge disposal with a performance record unmatched by any other sludge incinerator is made possible by the knowledge gained in supplying thousands of these furnaces to users all over the world.

Circular multiple hearth furnace development has been a Nichols preoccupation since its conception and has continued to be so with each successive improvement in design and scope of application. Some of the milestones in this history are:

1889—First circular multiple hearth furnace, the Nichols Herreshoff.

1909—First low pressure air cooled furnace shaft and rabble arms.

1931—First multiple hearth furnace for the incineration of sewage sludge.

19—Look for the next Nichols development.

Nichols Herreshoff
Multiple Hearth Dryer-Incinerator

Nichols Engineering & Research Corp.
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40 S. Los Robles Ave., Pasadena 1, Calif.
1477 Sherbrooke St. W., Montreal 25, Canada

how much does it cost to run the old model?

Even if you bought new today one of the old model chlorinators, you can actually scrap it right now and save money!

How can such a thing be?

In hundreds of installations using **F & P** Chlorinators it has been proven conclusively that costs of operation and servicing are so much lower than old style chlorinators that it actually *costs money* right from the first day of operation to have an old style chlorinator.

Fischer & Porter designed this new chlorinator right from the floor up. New materials are used throughout to make it impervious to corrosion. Encased in a fibre-glass cabinet, the new **F & P** Chlorinator handles chlorine —in fully enclosed, tightly sealed, corrosion resistant pipes and components. It is the best, safest, most efficient, easiest operating chlorinator ever devised.

Right from the purchase price you save money on an **F & P** Chlorinator And you save money every day thereafter, because you have less maintenance cost, less chance of breakdown with sky-high service charges, no need for multiple reserve units or scores of spare parts, no wasted chlorine gas lost through water seals.

As a top municipal official, as an ethical consultant, as a practical operating man—you must admit if all these things we say are true, you can't afford to ignore this new chlorinator.

It won't cost you a single penny to *get the facts* about the **F & P** Chlorinator. It will obligate you in no way. Why not write today?

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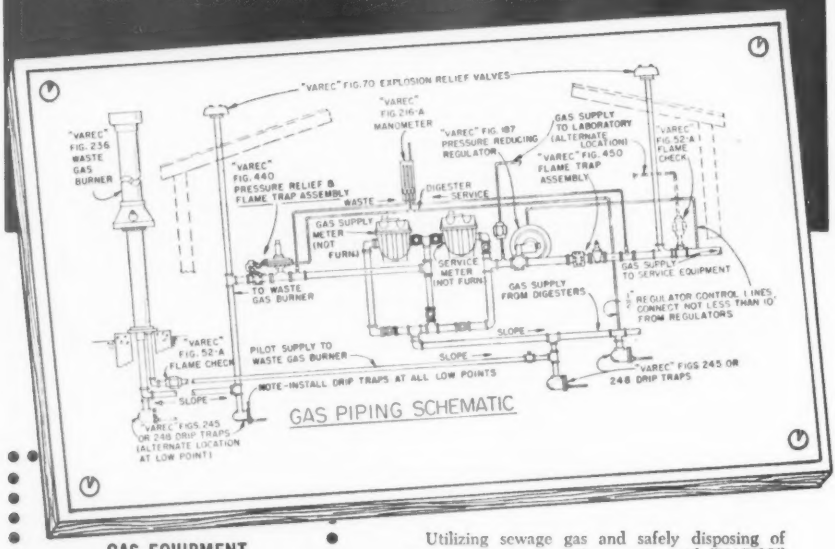
"VAREC" figures in *Your* SEWAGE TREATMENT PLANT DESIGN for SAFETY and GAS CONTROL


"VAREC" FIG. 70 EXPLOSION RELIEF VALVES
"VAREC" FIG. 236 WASTE GAS BURNER
"VAREC" FIG. 216-A MANOMETER
"VAREC" FIG. 197 PRESSURE REDUCING REGULATOR
GAS SUPPLY TO LABORATORY (ALTERNATE LOCATION)
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
"VAREC" FIG. 52-A FLAME CHECK
"VAREC" FIG. 440 PRESSURE RELIEF & FLAME TRAP ASSEMBLY
WASTE
DIGESTER SERVICE
GAS SUPPLY METER (NOT FURN.)
SERVICE METER (NOT FURN.)
GAS SUPPLY TO SERVICE EQUIPMENT
TO WASTE GAS BURNER
GAS SUPPLY FROM DIGESTERS
REGULATOR CONTROL LINES CONNECT NOT LESS THAN 10' FROM REGULATORS
"VAREC" FIG. 52-A FLAME CHECK
PILOT SUPPLY TO WASTE GAS BURNER
SLOPE
SLOPE
"VAREC" FIGS 245 OR 248 DRIP TRAPS
NOTE-INSTALL DRIP TRAPS AT ALL LOW POINTS
SLOPE
"VAREC" FIGS. 245 OR 248 DRIP TRAPS (ALTERNATE LOCATION AT LOW POINT)
GAS PIPING SCHEMATIC

GAS EQUIPMENT SPECIFICATIONS

PRESSURE RELIEF AND FLAME TRAP ASSEMBLY
"VAREC" Fig. No. 440

FLAME TRAP ASSEMBLY
"VAREC" Fig. No. 450

FLAME CHECK
"VAREC" Fig. No. 52A

EXPLOSION RELIEF VALVES
"VAREC" Fig. No. 70-1

WASTE GAS BURNER
"VAREC" Fig. No. 236

DRIP TRAPS
"VAREC" Fig. No. 245 (automatic)
"VAREC" Fig. No. 248 (hand operated)

MANOMETERS
"VAREC" Fig. No. 216A

"Varec"

Utilizing sewage gas and safely disposing of excess gas is an automatic operation with "VAREC" Equipment incorporated into your sewage plant design. With this equipment, accurate gas pressures are maintained in all service lines. As soon as the digesters make more gas than required for service, the pressure relief valve to the waste gas burner opens to permit safe burning of the excess.

Flame flashback to valuable equipment is prevented with "VAREC" Flame Traps and Flame Checks. The flame arresting element of the Flame Trap is designed to eliminate flame propagation of even more inflammable gases than encountered in sewage service. This element is the same as that used in "VAREC" Flame Arresters listed by the UNDERWRITERS' LABORATORIES for petroleum product storage.

Emergency explosion relief is accomplished with "VAREC" Explosion Relief Valves. These valves should be installed outside of any buildings.

An enlarged engineering drawing of the above gas piping detail will be sent upon request. If you design sewage treatment plants, write today.

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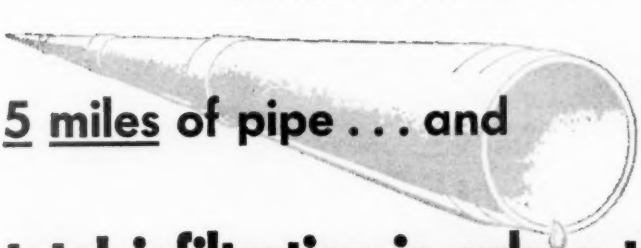


5 miles of pipe . . . and total infiltration is only a trickle . . .

. . . with Transite® Sewer Pipe

THE REDUCTION of ground-water infiltration brought about by the Ring-Tite® Joint—now standard on all sizes of Transite® Sewer Pipe—can lead to a number of cost-saving results.

For example, on one recently installed Ring-Tite System using 28,540 feet of Transite Sewer Pipe, in diameters of 6 through 18 inches, the infiltration per inch of diameter, per hour, per mile of pipe, came to a mere 0.85 gal. This low infiltration (including that from manholes and connections to house sewers) was achieved despite the fact that a considerable portion of this installation was below the prevailing ground water table. (For specification purposes, an infiltration allowance of 10 gallons per inch of diameter, per hour, per mile of pipe, may be used with Transite Sewer Pipe.)

Obviously, such minimum ground-water infiltration helps reduce the load on treatment plants, cuts down on treatment costs, and conserves plant capacity for future expansion needs. This reduced infiltration plus Transite's high flow capacity (Manning's N=.010) often permits the use of smaller diameter pipe for new installations.

For further information on how this Ring-Tite Joint, used with corrosion-resistant, asbestos-cement Transite Pipe can help reduce your sewage costs, write Johns-Manville, Box 60, New York 16, N. Y. Ask for folders TR-103A and TR-94A.

Tells more about Transite asbestos-cement Sewer Pipe with Ring-Tite joints—for non-pressure service. Ask for Brochure TR-103A.

Helpful to Engineers—Sewer Design Flow Chart Based on Manning Formula. Ask for Brochure TR-94A.

Johns-Manville TRANSITE SEWER PIPE

At Tacoma, Washington . . .

This Gleaming New Plant is Run at Peak Efficiency

WITH MODERN PFT EQUIPMENT

Sparkling clean and beautifully landscaped, Tacoma's new primary sewage treatment plant is a model of modern treatment methods and efficient operation. Completed in 1952, it uses PFT equipment for *effective treatment* and *more convenient operation.*

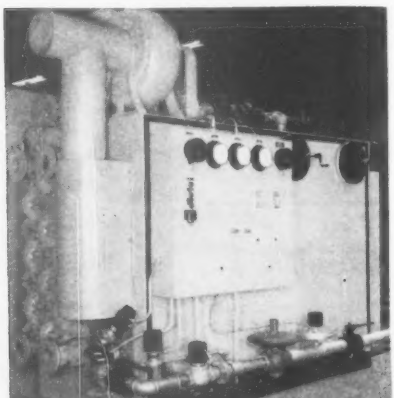
For the digestion tank, a *PFT 75' Floating Cover* was installed for positive scum submergence and more flexible capacity (the cover simply rises or lowers with additions and withdrawals). The snug fitting cover eliminates odor and fly nuisance, and explosion hazards are reduced because gas collected under the cover is maintained at positive pressure under all operating conditions.

For added convenience, a *PFT Cover Position Indicator* in the Control Building tells the operator at a glance the position of the cover.

A *PFT Heater and Heat Exchanger* unit automatically provides building heat and maintains close temperature control of the digester. Fired by gas *or* oil, it cuts fuel costs substantially by utilizing all gas produced in the digester. Tacoma's efficient digester operation is largely due to this close, automatic heat control!

Other PFT equipment in the new plant includes the following Gas Safety equipment—Heater Flame Trap; Pressure Relief Waste Gas Flame Trap; Waste Gas Burner; Pilot Line Flame Cell; Drip Traps.

The Tacoma plant's success results from close cooperation among three key men—C. S. Seabrook, Sanitary Engineer; Louis E. Fox, City Engineering Department; and Lyman Ketcham, Chief Operator.



PFT#1000 Digester Heater & Heat Exchanger

Design of plant by / Engineering Office of Clyde C. Kennedy

P.F.T.

waste treatment equipment exclusively since 1893

PACIFIC FLUSH TANK CO.

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 26 **August, 1954** **Number 8**

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W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois

Herbert P. Orland, *Associate Editor* Dr. F. W. Mohlman, *Advisory Editor*

Mrs. A. H. Skates, *Editorial Assistant*

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This Duo Clarigester-Duo Filter Team is installed at a restaurant and service area on the Pennsylvania Turnpike

Here's an actual case history that speaks for itself. Complete treatment including sludge digestion was required for a population equivalent of 3000. The consulting engineer designed two alternate plants . . . one using conventional equipment and one using Dorr "Duo" units. This is the breakdown:

ALTERNATE #1
One 30' dia. Duo Clarigester
One 38' dia. Duo Filter
TOTAL — 2 UNITS

ALTERNATE #2
Two 22' dia. Clarifiers
Two 27' dia. Filters
One 30' dia. Digester
TOTAL — 5 UNITS

And don't forget — both plants were designed for the *same* flow, to provide the *same* degree of treatment. Obviously, Alternate #1 was selected for the job on a lower first cost basis. Plus factors were substantial savings in space and the simplified operation inherent in Clarigester design.

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Sewage Works

SCIENTIFIC BASIS FOR LIMING OF DIGESTERS *

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The practice of liming digestion tanks to overcome so-called "starting trouble" or to keep old units in satisfactory balance has had a rather hectic history. As with so many practices which are more of an art than a science, the pendulum of thought is apt to swing back and forth from a favored position to an unfavored position rather rapidly, depending upon the experiences of workers in the field and their sphere of influence.

There is no question but what the pendulum of thought was swung quite radically in disfavor of liming practice by articles of Buswell (1) and Schlenz (2) in which they expressed a strong opposition to the practice. Although several discussions of the subject have ensued before professional groups (3)(4), it is questionable whether the use of lime has recovered much of its original favor. During the past two years the authors' personal attention has been drawn to several instances of "stuck" digesters where the use of lime had been shunned. The increased incidence of an old problem indicated the need for further study of liming practice.

Theoretical Considerations

It is quite well recognized that satisfactory digestion of organic matter under anaerobic conditions depends upon having two totally different groups of bacteria living harmoniously in the same environment. One group, normally present in sewage sludge in great numbers and capable of very rapid rates of reproduction, consists of saprophytic organisms which attack the complex organic substances, such as fats, carbohydrates, and proteins, and convert them to simple organic compounds. Among these saprophytic organisms are many acid-forming bacteria, which produce low molecular weight fatty acids, such as acetic and proprionic, during degradation of the organic matter. Such acids are produced in sufficient quantities in some cases to lower the pH to a level where all biological activity is arrested and a "pickled" or "stuck" digester results.

The second group of organisms of importance in anaerobic digestion are the methane-forming bacteria, which are capable of utilizing the acid and other end-products formed by the first group of organisms. It has been demonstrated (5) that the methane-formers are sensitive to pH changes and proliferate within a narrow pH range of about 6.5 to 8.0. Unfortunately, these organisms do not occur in great numbers in raw sewage sludge nor does their reproduction rate compare with many of the saprophytic organisms; consequently, organic acids may be formed faster than the limited population of methane-formers can assimilate them and, as a result, the accumulated acids reduce the pH level to even more unfavorable conditions for the methane-formers.

* Presented at 1953 Annual Meeting, New England Sewage and Industrial Wastes Association; East Providence, R. I.; Nov. 5, 1953.

The progression of events which occur in a digestion tank may be likened to those which take place on a modern factory assembly line. If Crew No. 2 is unable to keep pace with the onflow of end-products from Crew No. 1, it soon becomes engulfed unless provision is made to sidetrack the products from Crew No. 1 or a message is passed to it to slow down. If Crew No. 1 is not instructed to slow down, but their products are simply sidetracked, permanent relief can only be obtained by increasing the number of workers in Crew No. 2.

Just as the workers on an assembly line use an alarm system to warn others ahead of them that they are in distress, operators of anaerobic digestion units use the volatile acids determination as an alarm system to indicate when the methane-formers, Crew No. 2 in a digestion tank, are in danger of being immobilized.

It has been noted that an assembly line crew in distress need not warn the workers on the line ahead of them to slow down, provided they have facilities for sidetracking the oncoming materials and can increase the size of their working crew within a reasonable period of time. This is the exact situation existing within a digestion tank. The side track between the saprophytic organisms and the methane-formers is provided by the buffering substances present, which neutralize the organic acids, prevent a serious drop in pH, and allow the methane-formers to gain in numbers to accommodate the onflow of materials. The length of the side track in digesters is directly related to the amount of buffering materials present (Figure 1). From an engineering viewpoint, the greater the buffering capacity the greater is the factor of safety.

Primary sludge is notoriously poor in buffering capacity, whereas actively digesting mixtures are much richer. Buffering capacity is normally measured by determining alkalinity or, in other words, the resistance it offers to change in pH upon the addition of acids. The buffering capacity of raw sludge is almost entirely due to the bicarbonates present in the carriage water, mainly calcium and magnesium. The buffering capacity of digesting sludges is due to bicarbonates of calcium, magnesium, and ammonium. The calcium and magnesium bicarbonates are formed largely from the decomposition of calcium and magnesium soaps.

$$\left.\begin{matrix}\text{Ca soap}\\ \text{Mg soap}\end{matrix}\right\} + \text{Anaer. Bact.} \rightarrow \underbrace{CaO + MgO + CO_2 + H_2O}_{Ca(HCO_3)_2 + Mg(HCO_3)_2} + CH_4$$

The ammonium bicarbonate results from the bacterial decomposition of proteins which yields:

$$\text{Protein} + \text{Anaerobic Bact.} \rightarrow \underbrace{NH_3 + CO_2 + H_2O}_{NH_4HCO_3} + CH_4$$

FIGURE 1.—Presence of extra buffering capacity in strong (actually digesting) sludge mixtures gives methane-formers time to gain in numbers; lack of buffering capacity in weak (primary) sludge overloads methane-formers with acids formed as an intermediate product.

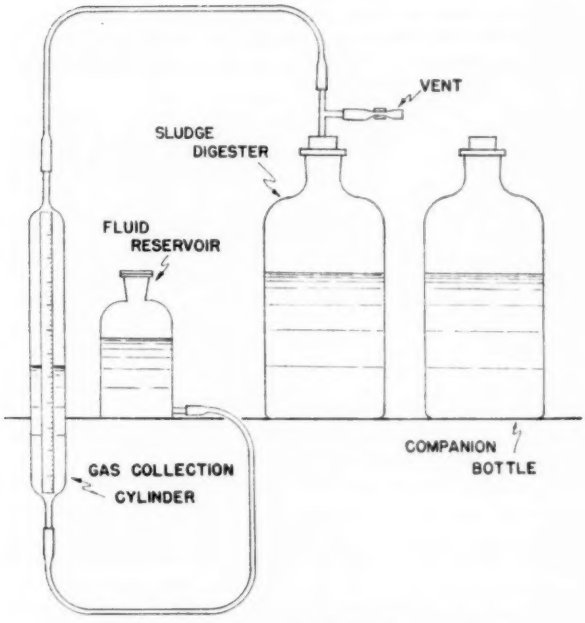

FIGURE 2.—Experimental digester arrangement.

Since it is known that raw sludge is deficient in buffering capacity, that highly buffered materials are most resistant to change in pH, and that the natural buffers in digesting sewage sludge consist largely of calcium, magnesium, and ammonium bicarbonates, it seems reasonable to conclude that the judicious addition of lime to neutralize organic acids in order to maintain favorable pH values, will result in a desirable climate for methane-formers, thereby allowing normal digestion to progress and at the same time adding to the total buffering capacity of the system.

It is recognized that attempts to use lime in the control of digesters have often been claimed to be without effect and claimed by some to be detrimental. It is recognized, also, that the problem of mixing the lime intimately throughout the sludge mass has been a difficult one and that pH measurements obtained could easily be misleading. For these reasons it was deemed necessary to use some other basis for determining the lime needed. Since the volatile acids are responsible for the difficulties in digesters which make it desirable to add lime, it was considered that they should serve as a convenient basis for determining lime requirements.

Method of Study

This study was restricted to the liming of "stuck" digesters to relieve such conditions and hasten the development of normal digestion.

Raw sludges were obtained from the activated sludge plant at Leominster, Mass., and the Nut Island plant of the Metropolitan District Commission, Boston, Mass. The sludge from the former consisted of a mixture of primary and excess activated sludges whereas the latter consisted solely of primary sludge.

Eight-liter quantities of the raw sludge from each plant were charged into each of 12 digesters (Figure 2).

TABLE I.—Volatile Acids and Lime Additions on Seventh Day

Digester	Vol. Acids (p.p.m.)		Vol. Acids Neutralized by Addition of Hydrated Lime (%)	
	Leominster	Nut Island	Leominster	Nut Island
1 and 1a	5,090	3,960	0	0
2 and 2a	5,380	3,860	25	50
3 and 3a	5,600	3,820	50	75
4 and 4a	5,230	4,140	75	100
5 and 5a	5,170	4,460	100	150
6 and 6a	—	4,240	—	200

Six of the digesters were equipped with gas collection devices; the other six, or companion, digesters were fitted with loose-fitting stoppers to allow easy access for removal of samples to determine pH, volatile acids, alkalinity, and solids at desirable intervals. The digesters were maintained at 95° ± 2° F. After seven days had elapsed and acid conditions were well established, the six companion digesters with loosely-fitting stoppers were sampled and the contents analyzed. On the basis of the data obtained, hydrated lime, in the form of a slurry, was added to each of the digesters, as shown in Table I.

Experimental Results

Because of an accident (6) with one of the digesters containing Leominster sludge to which enough lime had been added on the seventh day to neutralize 50 per cent of the volatile acids (expressed as acetic acid), detailed discussion of the results obtained on this sludge is not given. However, the study demonstrated that the beneficial results were in direct proportion to the amount of lime added and that the addition of enough lime to neutralize 100 per cent of the volatile acids showed no detrimental effects whatsoever. Since, on the seventh day, the sludge contained approximately 5,200 p.p.m. of volatile acids (expressed as acetic), 3,200 mg. of $Ca(OH)_2$ per liter, or the equivalent of 26,700 lb. (13.35 tons) per m.g., were required to neutralize 100 per cent of the volatile acids.

The studies with the Nut Island sludge (7) were conducted sometime after those with the Leominster sludge, and, in view of the fact that no deleterious results had been obtained in the previous study, it was decided to investigate the effects of larger dosages of lime. Accordingly, it was planned to include studies with dosages of $Ca(OH)_2$ equivalent to 150 and 200 per cent of the volatile acids present on the seventh day, in hopes that a condition of overtreatment might be experienced.

Immediately after adding the indicated dosages of lime to the various digesters, measurements of the resulting pH were made (Table II). The sludge mass in digesters 5 and 6, receiving lime equivalent to 150 and 200 per cent, became very black and appeared completely dead for a matter of a few days. Unfortunately, attempts to follow the changes in pH, volatile acids, alkalinity, and solids by studies on the contents of the companion digesters, with the loosely-fitting stoppers, were nullified, as it was demonstrated that the reactions proceeded most rapidly in the companion digesters, which were opened periodically to withdraw sludge samples for analysis. Consequently, the discussion of the results is limited to observations on

TABLE II.—pH of Sludge Mixtures Following Addition of Lime

Digester	Vol. Acids Neutralized[1] (%)	pH
1	0	4.90
2	50	5.55
3	75	5.90
4	100	6.40
5	150	8.30
6	200	10.20

[1] Equivalent to volatile acids expressed as acetic.

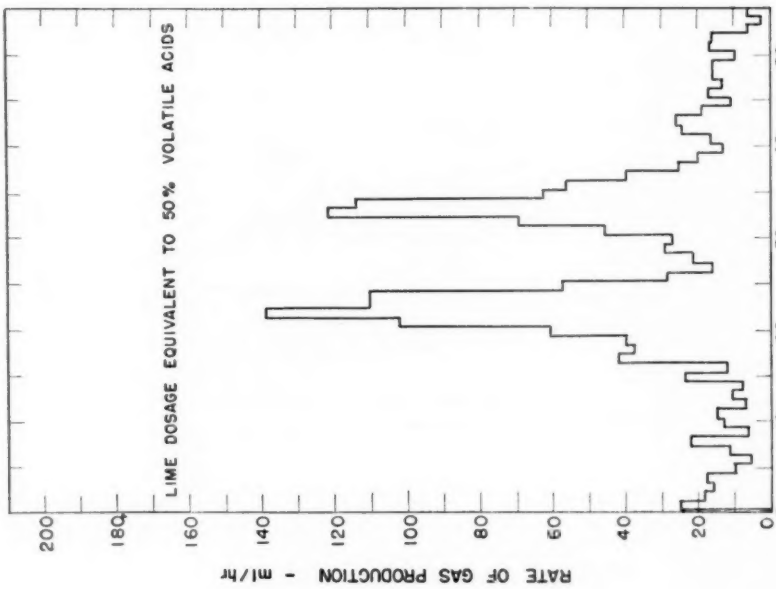

FIGURE 4.—Rate of gas production, digester No. 2.

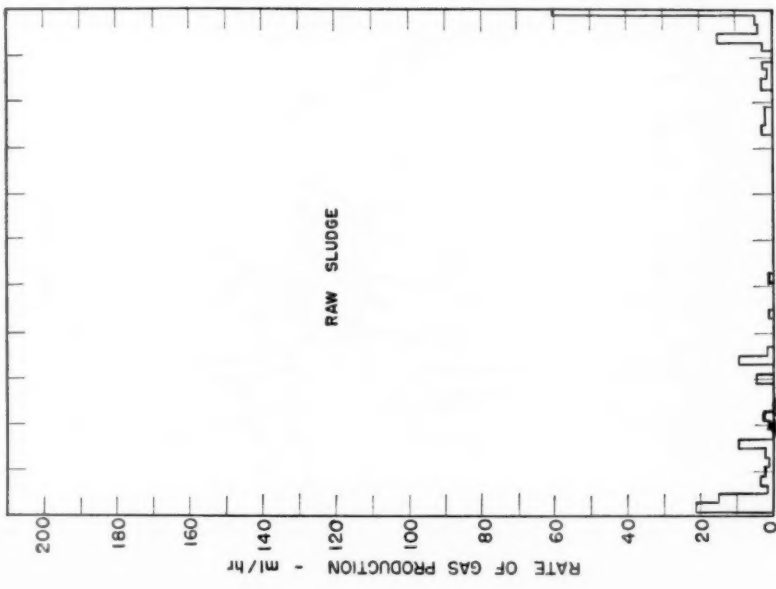

FIGURE 3.—Rate of gas production, digester No. 1.

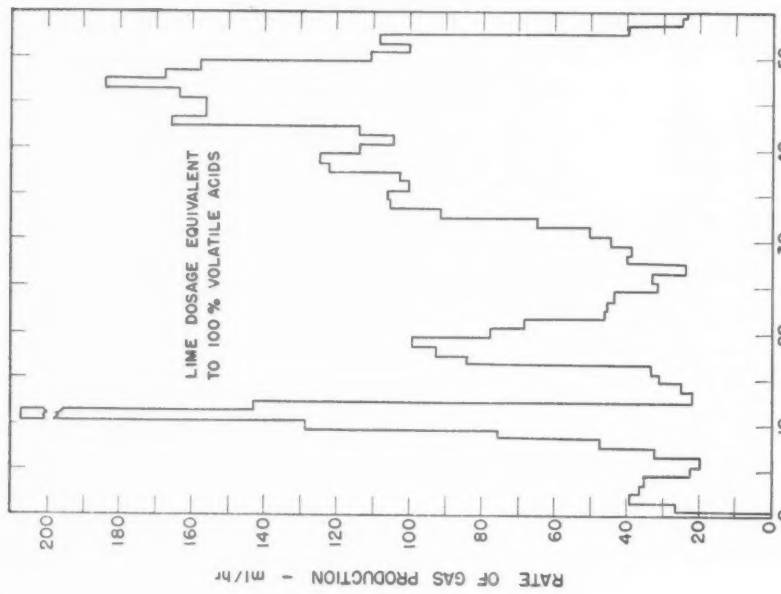

FIGURE 6.—Rate of gas production, digester No. 4.

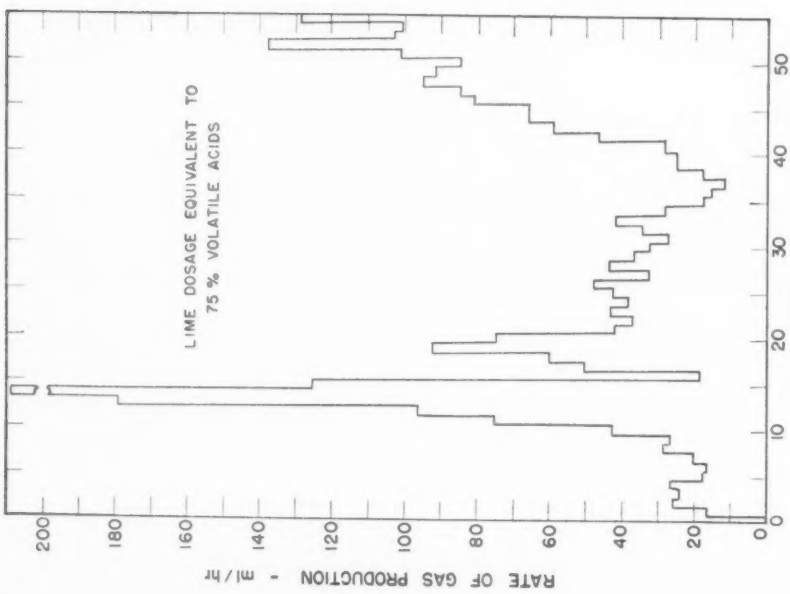

FIGURE 5.—Rate of gas production, digester No. 3.

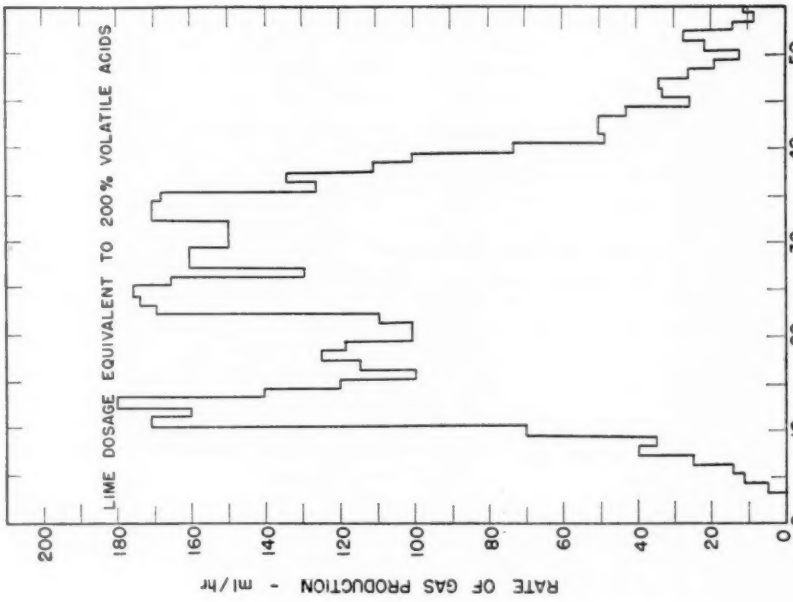

FIGURE 8.—Rate of gas production, digester No. 6.

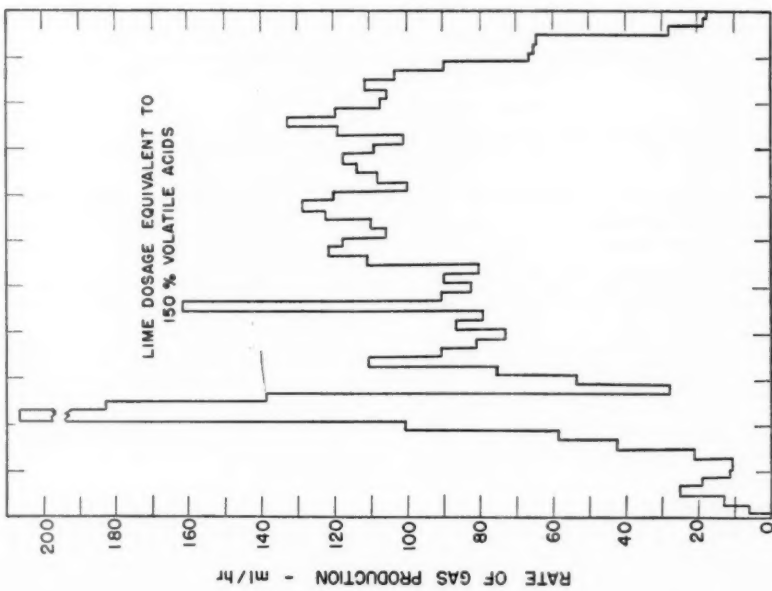

FIGURE 7.—Rate of gas production, digester No. 5.

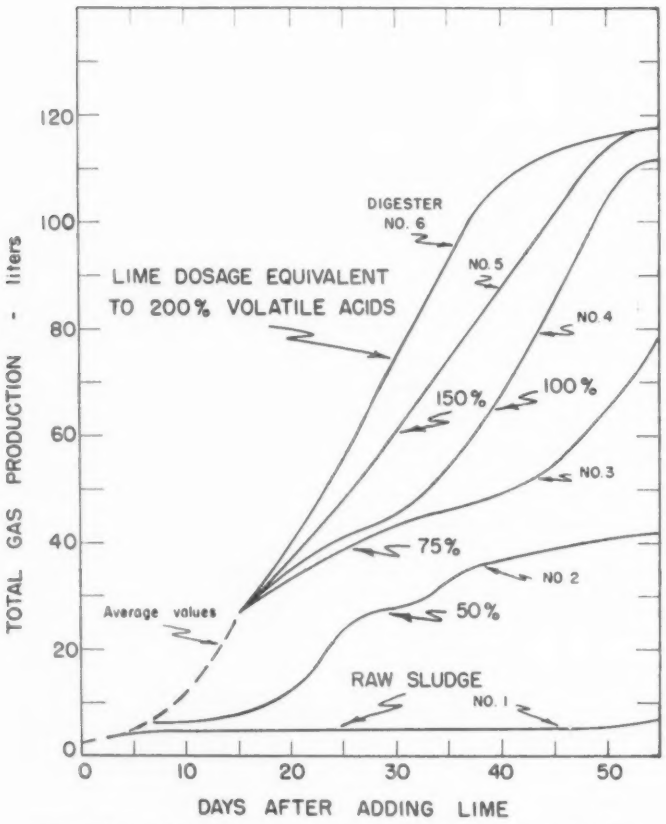

FIGURE 9.—Effect of lime dosage on cumulative gas production.

the behavior of the digesters with respect to gas production.

The effect of liming can best be observed by comparing the gas production curves for all six of the digesters (Figures 3 through 9). From these curves it will be observed that the addition of lime in limited amounts, say up to 100 per cent, caused a momentary response in gas production which was followed by a period of low gas production that persisted for shorter and shorter periods of time as the amount of lime added increased. In the case of the digesters receiving 150 and 200 per cent lime, the initial production of gas was delayed somewhat; but when active gasification did start gas production remained at high and uniform levels until digestion was essentially complete.

TABLE III.—Volatile Acids *vs.* Lime Dosages after 55 Days of Digestion

Digester	Vol. Acids Neutralized on 7th Day (%)	Vol. Acids (p.p.m.)	pH
1	0	4,040	5.10
2	50	3,540	6.40
3	75	220	7.30
4	100	100	7.25
5	150	120	7.20
6	200	180	7.20

Figure 8 shows cumulative gas production curves for all six of the digestion systems. Table III gives data

relating the volatile acid content and pH of each digestion mixture on the 55th day, when the study was terminated. These data verify that digestion was practically complete in digesters 4, 5, and 6, which had received the greater lime dosages.

Discussion

The need for a satisfactory buffering system within any sludge mass undergoing decomposition in which methane gas is a desired product seems to be well recognized. Not only is the presence of buffering substances necessary, but they also must be present in sufficient concentration to withstand the onslaughts of attack by volatile acids released in appreciable amounts from time to time, which might otherwise reduce the pH to levels inhibitory to normal behavior of the methane-formers.

The subject of proper buffering systems for anaerobic sludge digestions has been investigated by Pershe (6). His results have shown that ammonium carbonate, which is readily converted to ammonium bicarbonate in a digesting sludge, is, perhaps, somewhat superior to lime. However, on the basis of the excellent results obtained with lime when sewage sludges were involved, and the fact that it is such a cheap chemical, there seems to be little reason to consider other chemicals in such cases. However, where nitrogenous wastes are absent or present in limited amounts, it undoubtedly would be desirable to supplement lime additions with sufficient ammonium hydroxide to supply the nutritional requirements for nitrogen.

It is not surprising that the addition of lime for the control of favorable reactions in sludge digesters has had such a varied history when one considers the problems involved in introducing lime in a satisfactory manner into an old-style digester. Fortunately, most modern digestion tanks are equipped with recirculation or mixing facilities, which allow addition of lime in a manner which will allow satisfactory mixing.

In the studies reported, the entire amount of lime required was added batchwise. This will not be possible normally, or even desirable, in actual plant practice. Lime additions should be made on the basis of continuous feeding over a period of several days; thus, the development of unfavorably high pH levels can be avoided. Although these studies have shown that the pH can be raised to levels as high as 10.2, there seems to be no reason to tempt fate.

It should be remembered that additions of lime which raise the pH above 5.0 will react with CO_2 to form calcium bicarbonate and that this affinity for CO_2 is so great that CO_2 will be removed from the gas above the sludge and, in some cases, may cause negative pressures to develop, possibly damaging equipment. Therefore, lime additions to "stuck" digesters should be made when a manhole is open to allow entrance of air, and such manhole should not be closed until active gasification is well established. When tests show that a positive pressure is maintained within the system, the manhole may be closed.

Summary

1. Laboratory studies with primary sludge and with a natural mixture of primary and activated sludges have shown the addition of lime to be a practical means of relieving "stuck" digesters.

2. The quantities of lime needed can best be determined by reference to the volatile acids present.

3. Lime additions made in amounts equivalent to 25, 50, 75, 100, 150, and 200 per cent of the volatile acids, expressed as acetic acid, were found to have desirable effects which were in direct proportion to the amount of lime

added, 200 per cent giving the most satisfactory results.

4. Dosages of lime as great as 21.75 tons of hydrated lime per m.g. of digesting sludge were used in these studies without detrimental effect. In fact, beneficial results were obtained.

5. pH levels were raised to 10.0 by batch addition of lime without the development of adverse effects.

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A STUDY OF THE MECHANISM OF BIOCHEMICAL OXIDATION

A study of the mechanism of biochemical oxidation of solutions and colloidal suspensions of organic matter has been carried out by N. L. Nemerow of North Carolina State College. The study was sponsored by the National Science Foundation.

A progress report covering the period September 1953 to March 1954 showed the following:

When 500-p.p.m. glucose solutions were aerated for 24 hr. in the presence of an adapted dispersed growth of bacteria, the average reduction in total solids was 30 per cent. Also, the average difference in the total solids determined before and after settling (following the aeration period) was approximately 18 per cent. Neither the rate of settling nor the quantity of settleable solids appeared to change much during the aeration period. The B.O.D. of the solution, however, decreased 50 per cent during the 24-hr. aeration period.

Of the total reduction of 45 per cent in dissolved organic solids effected in 24 hr., 73 per cent occurred during the first 6 hr. In the same time the pH of the solution dropped from 8.3 to 7.3. Also, the total bacterial count increased during the first 6 hr., then returned to approximately the initial conditions after 24-hr. aeration.

The dissolved organic solids were shown to be removed by actual oxidation; a small proportion of the dissolved organic solids were removed by plain settling at all stages of the aeration. Oxidation, as demonstrated by the reduction of dissolved organic solids and B.O.D., resulted in a removal of 50 per cent of the glucose. The reduction in pH and increased bacterial count occurred simultaneously with the reduction in B.O.D. and dissolved organic solids.

DETERMINATION OF SYNTHETIC DETERGENTS IN SEWAGE

By Gail P. Edwards and Martin E. Ginn

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Market research has established that more than 90 per cent of the synthetic detergents used and subsequently found in sewage are of the anion-active type. Most of these are alkyl aryl sulfonates. In order to study the effect of detergents on sewage treatment, it was necessary to develop an accurate, rapid method of analysis of anion-active detergents in sewage.

Although considerable work has been done in developing analytical methods, those proposed are inaccurate because of interference by substances normally appearing in sewages and effluents. The Evans (1) method, which depends upon the extracting of methylene-blue salts of anionic detergents with chloroform and determining the concentration colorimetrically, is subject to errors because of interference by nitrates, nitrites, thiocyanates, and protein. Modifications (2) (3) (4) proposed to correct the errors have improved the method, but inaccuracies (5) still exist.

The two-phase titration method of Barr *et al.* (6) depends upon the titration of an anion-active detergent with a cation-active agent, cetyltrimethylammonium bromide (CTAB), in the presence of chloroform, and the use of an acid dyestuff dissolved in the water layer. The cationic agent combines with the anionic detergent initially. When all of the anionic detergent has been used up, a slight excess of titrating reagent forms a colored cationic detergent salt of the dyestuff, which is soluble in the chloroform. The end point is indicated by coloring of the organic solvent layer. Lewis and Herndon (7) tested this method on river water and sewage and reported that it performed satisfactorily in the presence of a number of organic substances.

The two-phase titration method seemed the most promising from the standpoint of simplicity and speed of operation. The Barr method and its modification by Lewis and Herndon worked very well in distilled-water systems, as the chloroform separated out from the water fairly rapidly after the layers had been mixed. With sewage, however, a very heavy emulsion was formed which in some cases was stable for more than 1 hr. Although addition of various hydrocarbons or inorganic salts had no effect on the stability of the emulsion, it could be avoided by using a lighter-than-water solvent, such as toluene, and by centrifuging the mixture. The centrifuging operation, which can be done in about 1 min., resulted in a clear organic layer.

In alkaline solutions, soap reacts with the CTAB reagent and is determined along with the synthetic detergent. The titrations were therefore made at a low pH, where the soap is converted to the inactive fatty acid. However, at a low pH the acid form of bromphenol blue moves into the solvent layer prematurely, so that it was necessary to substitute another dyestuff, azo phloxine. In distilled water, the calibration curves for both dyes are straight lines, differing only in slope when milliliters of CTAB are plotted against p.p.m. of detergent.

Preliminary tests also showed that the toluene-water system is too readily affected by the presence of sodium

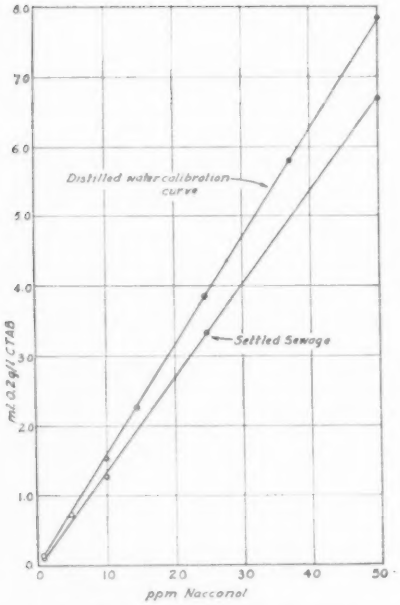

FIGURE 1.—Comparison of water and sewage curves for two-phase titration method; hexane-azo phloxine-water system; phthalate buffer at pH 4.

chloride. The substitution of a commercial hexane for toluene increased the tolerance for sodium chloride from 250 p.p.m. to 1,000 p.p.m.

A calibration curve was prepared using solutions of 0, 1, 5, 10, 15, 20, and 25 p.p.m. of Nacconol NRSF in distilled water. The volume of CTAB required by distilled water as a blank was subtracted from the volumes used by the various amounts of detergents. The values are plotted in Figure 1. A calibration curve prepared in the same way using Nacconol dissolved in sewage should have produced a line identical with the distilled-water curve. However, the curve produced with sewage diverged from the distilled-water curve to give increasingly lower results.

Study indicated that the divergence was not caused by suspended or colloidal material in itself, nor was it due to a difference in electrolyte concentration. Tests were made using the methylene-blue extraction method of Degens *et al.* (4) to determine whether it, too, produced different calibration curves with distilled water and sewage. Evans (1) had reported that results with sewage were lower than expected, but considered the difference to be experimental error. As shown by Figure 2, the calibration curves using the methylene-blue extraction method in water and sewage were very similar to those obtained by the two-phase titration method.

Valko (8) had pointed out that proteins have a very high affinity for synthetic detergents and combine with them to form protein-anionic detergent complexes at any pH below the isoelectric point of the protein. In acid media, proteins develop a positive charge on the amino groups, becoming highly charged cations. To test the effect of protein and related compounds on the two-phase titration method, various amounts of gelatin, proteose peptone, ovalbumin, methyl amine hydro-

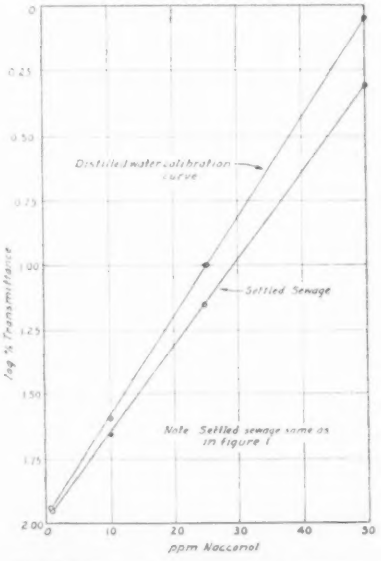

FIGURE 2.—Comparison of water and sewage curves for methylene-blue extraction method.

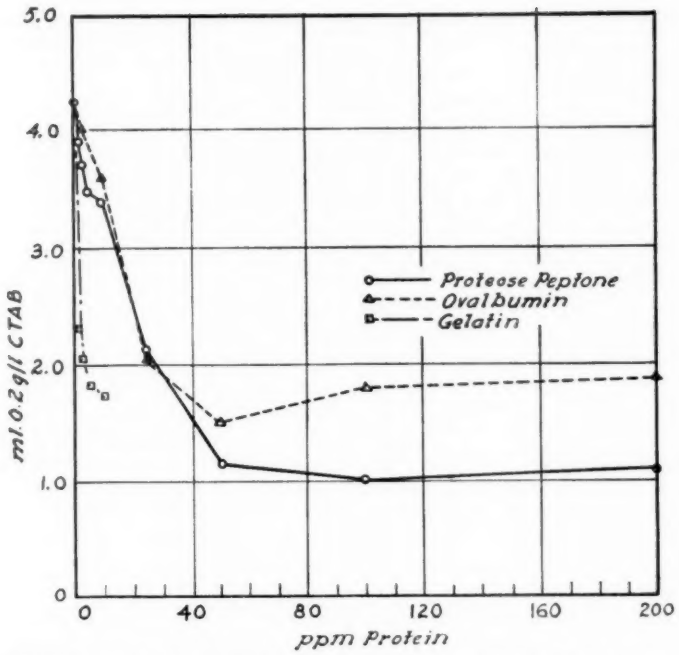

FIGURE 3.—Effect of protein on the two-phase titration method; 50 p.p.m. Nacconol at pH 3 using azo phloxine.

chloride, p-phenylene-diamine dihydrochloride, and glycine were added to a solution of 50 p.p.m. Nacconol in distilled water and the detergent was determined at pH 3. Figure 3 shows that even a few p.p.m. of proteins (such as gelatin, protease peptone, and ovalbumin) decreased markedly the amount of detergent recoverable. The amine compounds, such as glycine, methyl amine hydrochloride, and p-phenylene-diamine dihydrochloride, affected the results only slightly.

The proteins did not reduce the recoverable Nacconol concentration to zero, but with increasing amounts of protein a minimum point was reached after which the recoverable amounts increased. This is explained by the fact that after the protein has combined with detergent an excess combines with the dye, which is also anion-active. The formation of a protein-dye complex prevents the dye from moving into the organic solvent layer until a sufficiently large excess of CTAB displaces it from the protein.

The effect of protein on the reaction was shown when the experiment was repeated without the addition of any detergent. The amount of CTAB required increased with increasing amounts of ovalbumin. An attempt to eliminate the protein interference by the addition of chemicals such as sodium tungstate and sodium metaphosphate was unsuccessful. Although it was realized that a protein does not react with anion-active detergents at a pH above the iso-electric point, an alkaline reaction was avoided because of the potential danger of soap interference. A series of tests was made with samples containing 40 p.p.m. ovalbumin and 40 p.p.m. of Nacconol at various pH values. Figure 4 shows that above pH 7.0 the protein did not interfere. It is important to note that

the iso-electric points of most common proteins are below pH 7.

Calibration curves with Nacconol in distilled water and in sewage at pH 8.0 were again obtained; although the curves were closer together than before the correction was made for protein, they were not identical and the presence of other interfering cationic substances seemed indicated.

Some of the earlier tests had indicated that the titration of Nacconol solutions in waters of varying hardness resulted in different end points. Hard waters seemed to require less CTAB solution than soft ones for the same detergent content. A series of samples containing 50 p.p.m. of Nacconol, but varying amounts of calcium, magnesium, and sulfate ion, was titrated using bromphenol blue as the indicator at pH 8.0. Phosphate was used to buffer the system. The results (Figure 5) indicate that even 25 p.p.m. of calcium or magnesium gave a result 10 to 15 per cent less than theoretical. Sulfate ion interferes in much the same way as sodium chloride. That calcium and magnesium salts of the alkyl benzene sulfonates do not react the same as the sodium salt may be due to the lower solubility of the alkaline earth salts. The rise in the calcium ion curve was caused by the formation of a calcium phosphate precipitate, which accumulated at the hexane-water interface. This precipitate seemed to adsorb the cetyltrimethylammonium salt of the dye, preventing it from freely entering the hexane layer.

Although sodium tripolyphosphate

TABLE I.—Results of Two-Phase Titrations of 50-p.p.m. Nacconol Solutions

Sample	CTAB Sol.[1] Req. (ml.)
50 p.p.m. Ca + 50 p.p.m. Mg	3.00
50 p.p.m. Ca + 50 p.p.m. Mg + 1,000 p.p.m. EDTA	3.41
1,000 p.p.m. EDTA	3.43
Blank[2]	3.42

[1] 0.2 g. CTAB per liter distilled water.
[2] 50 p.p.m. Nacconol in distilled water.

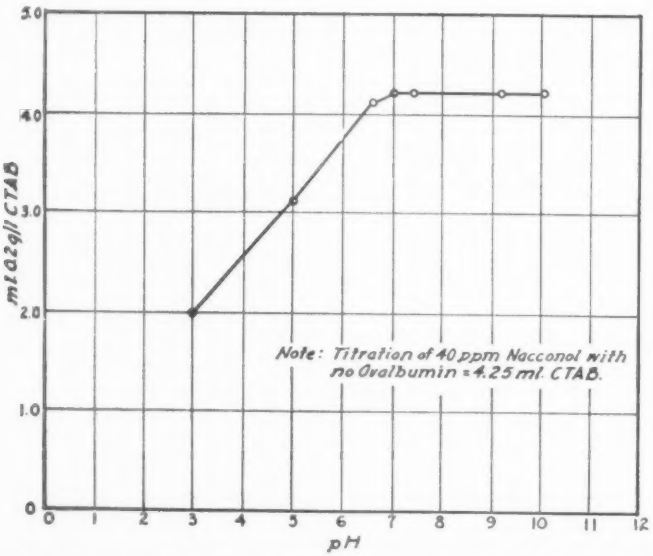

FIGURE 4.—Effect of pH on interference by ovalbumin; 40 p.p.m. ovalbumin and 40 p.p.m. Nacconol using azo phloxine.

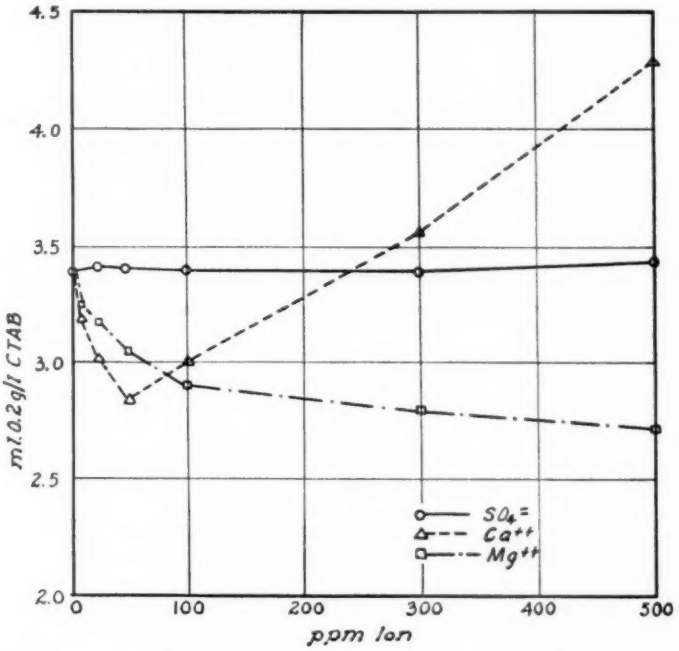

FIGURE 5.—Interference by hardness; 50 p.p.m. Nacconol; bromphenol-blue; phosphate buffer at pH 3.

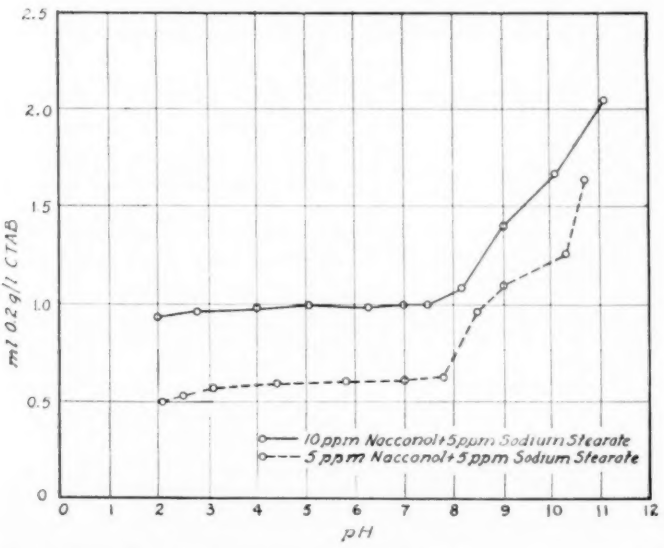

FIGURE 6.—Effect of pH on interference by sodium stearate using azo phloxine.

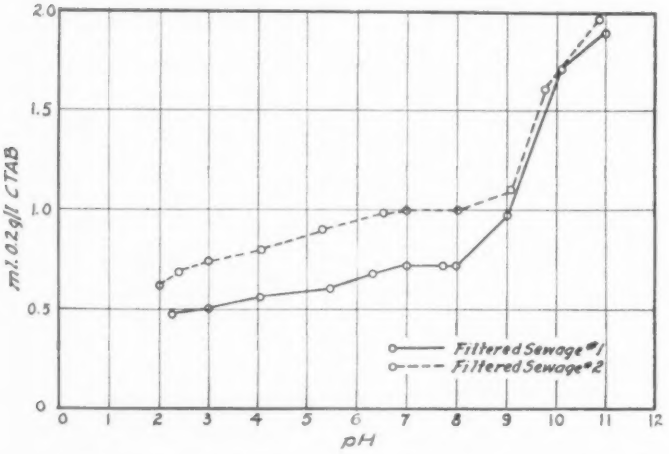

FIGURE 7.—Effect of pH on titration of two different sewages.

and sodium pyrophosphate were ineffective, EDTA (disodium salt of ethylene diamine tetraacetic acid) completely removed the interfering calcium and magnesium ions (see Table I).

The addition of 60 mg. of EDTA to a 25-ml. sample (2,400 p.p.m.) will prevent interference from hardness in amounts up to 500 p.p.m. as calcium carbonate.

In order to determine the relative magnitude of interference by protein and hardness, one sample of sewage with EDTA added was titrated at pH 3 to show the effect of protein, another

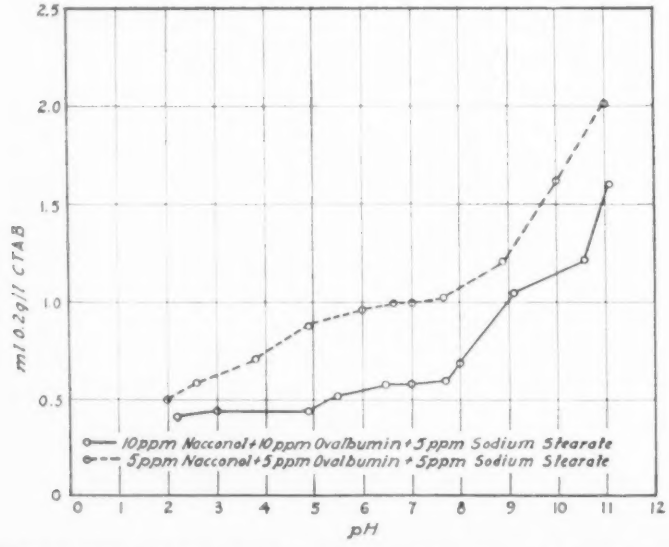

FIGURE 8.—Effect of pH on water system containing Nacconol, protein, and soap.

without EDTA was titrated at pH 8 to show the error caused by hardness, and a third sample with EDTA was titrated at pH 8 to eliminate both interferences. The series was repeated with distilled water using 0 and 50 p.p.m. of Nacconol. The results indicate that for this sewage the error caused by the presence of protein was greater than that from hardness.

To determine the effect of soap, increasing amounts of sodium stearate in distilled water were titrated at pH 7.5 and 8.0 using bromphenol blue as the indicator. The results showed that at pH 7.5 the tolerance for sodium stearate was 30 p.p.m., whereas at pH 8.0 it was only 10 p.p.m. Another series of tests (Figure 6), using 5 and 10 p.p.m. of Nacconol with 5 p.p.m. of sodium stearate at pH values ranging from 2.0 to 11.0, indicated that soap does not interfere between pH 4.0 and 7.5. It would appear, therefore, that interference from protein and soap could be eliminated if the reaction was carried on between pH 7.0 and 7.5.

In order to test this conclusion, two sewages were titrated at different pH's. using azo phloxine. The resulting pH curves (Figure 7) were compared with pH curves (Figure 8) derived from distilled water systems containing Nacconol, protein, and soap. In each case there is a region between pH 7.0 and 7.5 of non-interference for both the sewage and the distilled-water systems.

The recommended procedure for the determination of anion-active detergents in sewage follows.

MODIFIED TWO-PHASE TITRATION METHOD

Distilled-Water Calibration Curve

1. Prepare a master stock solution of 1.0000 g. per liter of Nacconol NRSF (or some fairly pure alkyl benzene sulfonate) in distilled water.

2. From the stock solution prepare test solutions of 0, 1, 5, 10, 25, and 50 p.p.m. Nacconol in distilled water. (More concentrations may be used if considered necessary.)

3. Pipette 25 ml. of test solution into a glass-stoppered centrifuge tube. The tubes should be made of heavy-duty glass; for best results they should have as large a volume as possible, since longer titrations yield more accurate results. Also, it is important that the tubes be as narrow as possible, since this enables the use of a small volume of solvent with a wide band in the tube. The less solvent used the sharper will be the end point produced by a small excess of CTAB reagent. (The tubes used in this study were approximately 80 ml. in volume and were designed to fit the 100-ml. cups of the International centrifuge, size 1, type SB. A centrifuge tube smaller in volume than 50 ml. is not recommended.)

4. Add 10 ml. pH 7.5 phosphate-EDTA buffer. (One liter of buffer solution contains 6.8 g. potassium dihydrogen phosphate, 6.0 g. disodium dihydrogen ethylene diamine tetraacetate, 900 ml. distilled water, sufficient 1 N sodium hydroxide solution—about 63 mls.—to raise the pH to 7.5, and water to make up to 1 l.

5. Add 2 ml. of 0.04 per cent bromphenol-blue solution or 0.1 per cent azo phloxine solution. (Azo phloxine GA extra concentrated CF is obtainable from General Dyestuff Corp.)

6. Add 5 ml. commercial hexane. (The hexane used was obtained from the American Mineral Spirits Corp.)

7. Titrate with a 0.2000-g.-per-l. distilled-water solution of cetyltrimethylammonium bromide, using a 5-ml. microburette calibrated to 0.01 ml., and shaking the system vigorously in an up-and-down motion after each addition of titrant.

8. Centrifuge as long as is necessary to obtain good separation of the two layers.

9. Examine the hexane layer, using a blank white sheet of paper as a back-

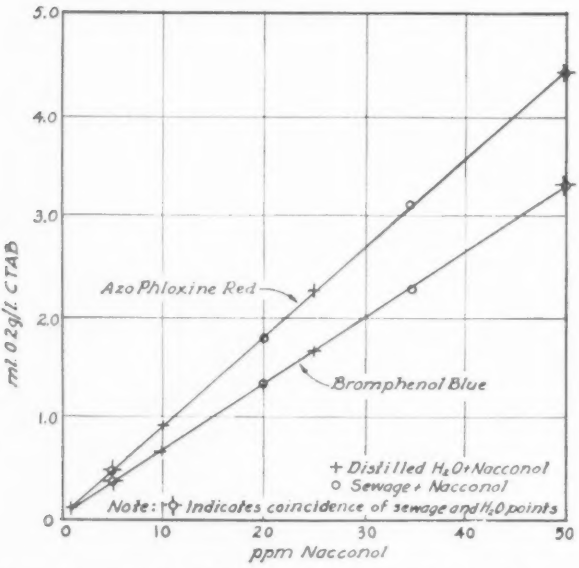

FIGURE 9.—Recoverability of Nacconol from sewage using the recommended two-phase titration method.

ground, to determine whether any color has entered it. The titration should be stopped only when it is certain that the hexane layer has become colored. It may be noted that for routine determinations additions of 0.05 ml. of titrant may be used. For the preparation of a good calibration curve and for fine work the additions should be dropwise at the end point. In any case, large doses of titrant may be added to bring the titration to a point just before the end point, beyond which small additions may be made.

10. Construct a graph plotting ml. CTAB *vs.* p.p.m. Nacconol. The plot should be a straight line; if not, the results should be checked.

Sewage Analysis

1. Shake the sewage thoroughly.

2. Filter 25 ml. of sewage through a small filter paper, using the coarsest paper available and collecting the filtrate in a centrifuge tube.

3. Wash the filter paper twice with 5 ml. of the pH 7.5 buffer solution, and add the washings to the filtrate.

4. Add the dye and hexane and proceed as previously described, titrating as before.

5. Using the calibration curve, determine the concentration of anion-active detergent in the sewage as p.p.m. Nacconol.

In analyzing the sewage a filtrate is used rather than the raw sample, as it was found that gross water-insoluble matter suspended in sewage dissolves in the hexane, giving it a greenish-yellow cast. This reduces the sharp-

TABLE II.—Titrations of Residues and Washings from Sewage Samples[1] with Bromphenol Blue as the Indicator

Sewage	CTAB Solution[2] Required (ml.)	
	Susp. of Residues Removed from Paper	Third Washing of Residues
1	0.06	0.07
2	0.07	0.06
3	0.06	0.06

[1] Distilled-water blank required 0.06 ml. CTAB solution.

[2] 0.2 g. CTAB per liter.

ness of the appearance of color so that it is extremely difficult to detect the end point. Filtering the sewage removes this difficulty without altering the detergent concentration in the sample. Table II gives typical results obtained by testing the residue and the third washing of the filter paper for the presence of detergent.

These results indicate that no titratable anionic detergent was left on the residue or on the paper.

A comparison of the results obtained with three samples of sewage to which 5, 20, 35, and 50 p.p.m. of Nacconol were added with distilled water containing the same concentration of detergent shows that identical straight-line plots result (Figure 9) when milliliters of CTAB solution are plotted against p.p.m. of detergent. The detergent originally present in the sewage was subtracted as a blank.

Summary

The two-phase titration method of Barr for determining anion-active detergents has been modified to produce a rapid accurate method for use with sewage. Interference by soap and protein in the usually expected amounts has been eliminated by adjustment of the pH to 7.0 to 7.5 during the reaction. The use of EDTA avoids errors caused by the presence of calcium and magnesium salts. The method is not affected by sodium chloride or sulfate in concentrations up to about 1,000 p.p.m. Thiocyanates, nitrates, nitrites, and urine do not affect the result. Either bromphenol blue or azo phloxine can be used as the dyestuff; in a calibration curve both give straight lines, but with different slopes.

Acknowledgments

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EFFECTS OF DETERGENTS ON SEWAGE AND SEWAGE TREATMENT AT MILITARY INSTALLATIONS*

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The effects upon sewage treatment of synthetic detergents used in place of soap may be classified under four headings, as follows:

1. Changes in B.O.D. and suspended solids per capita loadings in raw sewage.
2. Alteration of the distribution of organic load to various treatment devices within the plant.
3. Modification of the "treatability" of the material applied.
4. Introduction of special operating problems, such as frothing and phosphate removal.

Estimates are presented herewith of the type and magnitude of modifications that appear to be necessary or desirable in the design of military sewage plants in order to accommodate the new loading conditions so that the degree of treatment provided will be substantially unchanged. At the same time, it has seemed worth-while to include preliminary estimates of design changes that would be necessary if garbage grinders were installed in mess-hall kitchens.

Estimates presented herein cannot be regarded at the present time as being solidly based on conclusive and undisputed plant-scale experience. Practically all data have been obtained with municipal sewage containing various amounts of industrial wastes. On some topics, such as the effect of syndets on sedimentation, there exists much conflicting evidence. On other topics, conclusions based on laboratory research have not as yet been corroborated by investigations in the field. Therefore, it has been necessary to exercise judgment in selecting those experimental results from the now rather extensive literature that appear to be most closely related to conditions in military plants with their characteristic type of sewage.

It is pertinent to mention certain aspects of the experimental data thus far available that tend to limit their use for the purpose at hand, as follows:

1. Practically all studies have been made by dosing detergents in relatively low concentrations to sewage in the plant or in laboratory bottles. In actual use, however, syndets are first introduced in the kitchen and in the laundry, and are mixed with wastes in high concentrations and temperatures. Dilution and cooling occur in subsequent passage through sewers. These two modes of application may result in substantially different colloidal structures and degrees of dispersion of solids in the dosed sewage in the final dilution. It is axiomatic in colloid chemistry that the manner of preparation of a sol may be as important in determining its properties as are its chemical constituents.

2. In many investigations the "pure organic detergent" alone has been used without builders, sequestering agents, and fillers that ordinarily account for 50 to 70 per cent of the total weight of the packaged product. These compounds include sodium tripoly-

* Prepared for and approved by the National Research Council, Committee on Sanitary Engineering and Environment, and by the Subcommittee on Waste Disposal.

phosphate, tetrasodium pyrophosphate, carboxymethylcellulose, various sulfates, silicates, carbonates, and other chemicals. Some of the builders, particularly the polyphosphates, have a marked influence on the colloidal behavior and interfacial tension in sewage, even in extreme dilution, and therefore are important in the mechanism of sewage treatment.

3. The analytical methods for synthetic detergents in sewage have not yet been perfected to the degree that would be desirable for making engineering calculations regarding design of treatment plants and pollution load capacity of streams. In the present state of the analytic art, it is not possible to identify the various types of anionic detergents that may be present in sewage.

Types of Detergents

Of primary interest as constituents of military sewage are the anionic detergents, including the alkyl aryl sulfonates and secondary alkyl sulfates. Nonionics in special formulations (polyethylene ethers), and cationics (quaternary ammonium compounds), may be expected in somewhat higher concentrations than in typical municipal sewage, but except in unusual circumstances they will be unimportant. If present trends continue, it is estimated that eventually of the total amount of soap and syndets in military sewage 25 per cent will be soap, 60 per cent anionics, 15 per cent nonionics, and 5 per cent cationics.

Modifications in Sewage Composition

From a postwar review of the concentration of raw sewage at various municipal sewage plants, it would appear that no marked changes have occurred. On the average, there has been a slight decrease both in concentration and in per capita contribution. Also, the nationwide long-term trend toward lowered suspended solids concentration appears to have continued. Such changes as have occurred and will occur in the near future stem chiefly from three trends in modern living. In chronological order of inception, these are as follows:

1. Widespread adoption of automatic washing machines in the kitchen and laundry. This development, together with continued installation of air conditioners and home water softeners, has tended to increase water use and to reduce the concentration of organic matter in sewage.

2. Increased popularity of synthetic detergents. In household, restaurant, and laundry applications this increase has occurred at the expense of soap use, especially in hard-water areas. In other applications, however, the spread of synthetics has not resulted in an appreciable corresponding reduction in use of soap and soap products.

A number of the most important detergents have decidedly different B.O.D. characteristics from soap. For example, some of the sodium alkyl aryl sulfonates, which as a class comprise more than 50 per cent of total production, exert little or no B.O.D. with common seeding organisms. Syndets have the ability to solubilize and suspend substances not normally soluble in water. That they do this even in the presence of hydrogen and alkaline earth ions adds greatly to their utility. The dispersing and emulsifying action on oil and dirt of the new household detergents after dilution in sewers is more stable and longer persisting than that of soaps. These properties of synthetic detergents have resulted in changes in the organic content and colloidal structure of sewage that have altered its amenability to treatment in the various types of sewage plant units.

3. Accelerated rate of installation of household garbage grinders. The principal effect is augmentation of total and suspended solids in sewage, with some increase in the carbon : nitrogen ratio.

In assessing the relative importance of these trends, it must be observed that they did not originate simultaneously, nor are they proceeding at the same rates. The present effect on domestic sewage of increased water use from automatic washers is about 30 to 50 per cent of what it will be ultimately; the effect of the substitution of household syndets, about 50 to 65 per per cent of ultimate; and that of adoption of garbage grinders, only about 10 to 20 per cent of ultimate.

The result of the first two trends in bringing about lower concentrations and per capita contributions of B.O.D. and suspended solids is already being reversed by increases in ground garbage. With continuation of the latter trend, a marked increase in per capita weight of sewage-borne organic solids and some increase in their concentration may be expected. It may be further anticipated that during the coming decade relative amounts of fats in sewage will decrease in proportion to carbohydrates; the proportion of proteins may decrease slightly. Significant continued enhancement of the fertility of the mineral substrate deriving mainly from augmented phosphate concentrations is certain.

In evaluating the foregoing factors with relation to conditions in military installations, the following differences between normal military and municipal sewage have been taken into account. The former tends (a) to be more concentrated, (b) to have a greater proportion of volatile matter relative to total solids, (c) to have a higher proportion of grease, and (d) to exhibit larger and more rapid variations in diurnal flow.

Plant Loading

Consideration of the foregoing trends, together with an interpretation of the relevant experimental evidence, leads to the following predictions of effects in military sewage assuming complete adoption of garbage grinders and a 3:1 ratio of syndet: soap use:

1. A 25 to 40 per cent net increase in B.O.D.* With syndets, but without garbage grinders, a 5 to 15 per cent reduction in B.O.D. is estimated. A very significant factor in this connection, and one over which control may be exercised, is the type of detergent selected by the Quartermaster Corps for general issue. The two most widely adopted and generally useful domestic types of synthetic detergents on the market today are (a) alkyl aryl sulfonates, such as $C_{12}H_{25}-C_6H_4-SO_3Na$, and (b) fatty alkyl sulfonates, such as $CH_3(CH_2)_{10}—CH_2—OSO_3Na$. Some of the former types of compounds have little or no B.O.D. with common seeding microflora. Certain of these molecules, it has been shown, will pass directly through activated sludge and trickling filter plants without significant reduction in concentration. Their resistance to biochemical decomposition is probably to be attributed to the presence of a benzene ring. Alkyl sulfates, on the other hand, exhibit appreciable B.O.D.—in some cases approaching that of soap both as to availability (k) and total amount (L).† In determining the total plant load and effluent quality, a major factor is in the selection of the molecular type of detergent for general issue.

2. A 30 to 50 per cent increase in suspended solids. Sludge volumes may be doubled. With syndets but without garbage grinders, a 5 to 10 per cent decrease in suspended solids concentration and a 5 to 10 per cent increase in sludge volume are estimated.

3. With syndets but without grinders, a 15 to 25 per cent reduction in grease in raw sewage is estimated. Recoverable grease will probably be even further reduced because of the superior

* Somewhat less than corresponding estimates for municipal sewage.

† Where k and L refer to parameters in the first-order B.O.D. formulation.

stability and presistence of syndet emulsions relative to those formed by soap. As high as 60 per cent of the grease formerly removed in primary treatment may be expected to pass through to secondary biological units.

4. With syndets alone, the amount of B.O.D. removal in primary treatment will decrease from 20 to 35 per cent, with a corresponding increase in the loading of secondary units. It is not expected that increased primary detentions will be effective in restoring former efficiencies. In some cases, overloading of secondary units may be alleviated by installing chemical dosage and coagulation equipment ahead of primary sedimentation. This may be indicated particularly when chemicals and pH control are needed for phosphate removal.

On the basis of present evidence, it would appear that ground garbage will tend to restore the pre-syndet balance between primary and secondary treatment.

Sludge Digestion and Disposal

It is believed that recent municipal experience as to increases in sludge solids, changes in sludge concentration, and decreases in gas production may be applied directly to military plant design. A reduction in the amount and fuel value of gas from syndet substitution may be anticipated, but it seems unlikely that in the typical military plant the decrease will pose a critical heating problem. However, exceptions may occur in small northern posts.

Attention should be directed to the fact that, unlike soap, many anionic detergents contain significant quantities of sulfur. Increased hydrogen sulfide may be of significance in larger plants where gas-power generating equipment may be installed.

Frothing

With careful design of the detergents in general issue it should be possible to forestall some of the nuisances associated with frothing in activated sludge and contact aeration plants.* Most of the popular brands of household syndets form suds at dishpan temperature. Some of these, however, do not foam at the temperatures prevailing in sewage. Professor C. N. Sawyer, of the Massachusetts Institute of Technology, has suggested the following hypothesis to account for the delayed appearance of froth in aeration basins: (a) Initially there may be components in the commercial detergent mixture that effectively inhibit froth formation at sewage temperatures; (b) these components, if any, together with the burden of grease and spent soap accumulated by the syndets, prevent frothing in the initial stages of aeration; and (c) the components, the grease, and spent soap are readily subject to biochemical oxidation. With the elimination of these antifoaming constituents extensive frothing may occur in the downstream end of aeration tanks.

The most reliable froth control method is maintenance of a sufficiently high concentration of suspended solids in the mixed liquor. However, with the inherent variability of post populations in periods of national emergency, difficulties may be anticipated in carrying sufficient active sludge concentrations in aeration tanks at all times.

It will be recalled that in World War II, before the advent of detergents on a broad scale, troublesome frothing was experienced in certain underloaded contact aeration plants at posts in the Southern states. At that time a few operators introduced control measures similar to those currently being installed in high-rate activated sludge plants. Recent information as to de-

* It would seem that the mess sergeant, unlike the housewife, need not be pampered by the manufacturers to the extent of adding foaming agents *per se*, that have no merits relating to detergency.

sign and cost of spray and antifoam dosage equipment has been presented by Fuhrman and Rice (1) and Greeley (2). A list of chemicals with antifoam properties may be found in a recent symposium report (3).

Special Treatment

Two perplexing difficulties have been encountered in connection with the disposal by dilution of plant effluents containing synthetic detergents. These are (a) excessive fertility in receiving waters caused principally by available phosphorus (polyphosphate in builders), and (b) interference with water treatment caused by components of anionic detergents that resist treatment in sewage plants and self-purification mechanisms in streams (poor coagulation, sludge flotation, short filter runs, tastes, and odors). The evidence is now overwhelming that conventional "complete" sewage treatment does not solve these problems and with syndet still on the increase it may be expected that they will be intensified, especially in low flow years.

During World War II, many military posts discharged sewage into relatively small streams, and it must be anticipated that troublesome conditions from excessive phosphates and undecomposed detergents may arise on a considerable scale. Therefore, consideration should be given to phosphate removal, both by lime precipitation and by algal uptake in oxidation ponds. The latter possibility is particularly attractive in view of the established utility of oxidation pond treatment for posts in warm climates.

No practicable method has as yet been developed for removal of resistive detergents, such as the alkyl aryl sulfonates, that defy biochemical oxidation. However, microorganisms have recently been found that will quickly decompose such "difficult" compounds as formaldehyde, pyridine, piccolines, and chlorophenols, so that it is not unreasonable to have some assurance that similar results will be forthcoming with resistive anionic detergents.

Laundry Wastes

While, on the average, laundry waste amounts to only about 5 to 8 per cent of sewage flow in cantonments, serious operating problems were encountered in 1942–44 at several posts in which laundry work was done for adjacent military installations. At Fort Riley, Kans., laundry discharge constituted more than 25 per cent of the average flow; at Camp Forrest, Tenn., laundry waste at times entered the plant at the rate of 450 g.p.m. Flagrant instances of interference with sewage treatment occurred. With some adjustments in laundry practice, and with various makeshift arrangements, the worst effects of excessive laundry flow eventually were ameliorated.

In light of what is now known of the poor degree of treatability of many synthetic detergents used in laundries, and the decided bactericidal properties of other (cationics are used in hospital laundries), it would appear that due consideration should be given to potential problems at posts with large laundries. Arrangements for holding basins, integrating tanks, oxidation ponds, and other special treatment devices for laundry flow may be necessary in order to obtain satisfactory sewage treatment.

Quantitative Estimates of Design Modification

Some perception as to the degree of modification of military sewage plant design may be obtained from consideration of the following examples, in which quantitative estimates are made of effects of soap replacements by syndets and of ground garbage.

The calculations pertain to a plant with a 1.0-m.g.d. flow and raw sewage B.O.D. of 308 p.p.m. With 75 g.p.c.d., and 0.192 lb. B.O.D. per day, this cor-

responds to a population of 13,300. The sewage is treated by standard trickling filters.

Case 1. Normal; No Recirculation

Assuming 35 per cent removal in primary settling, the weight of B.O.D. in the filter influent will be (1.00 − 0.35) (308) (1) (8.34) = 1,668 lb. per day.

In order to meet the requirement of 600 lb. per acre-ft. per day stipulated in the "Engineering Manual," the required volume, V, of filter media is 1,668/600 = 2.78 acre-ft. Substituting in the filter efficiency formula (*Sewage Works Jour.*, **18**, 5, 970; Sept., 1946),

Per cent efficiency

$$= \frac{100}{1 + 0.0085\sqrt{600}} = 82.8\%$$

The concentration of B.O.D. in the plant effluent will be (1.000 − 0.828) (1668)/(1) (8.34) = 34.4 p.p.m. The over-all reduction in B.O.D. will be 100 (308 − 34)/308 = 88.8%.

Case 2. With Syndets, But No Ground Garbage; No Recirculation

Assume 10 per cent reduction in B.O.D. in the raw sewage, and that the primary settling efficiency is reduced to 25 per cent.

The weight of B.O.D. in the filter influent will be

$$(1.00 - 0.25)\ (1.00 - 0.10(308)(1)\ (8.34) = 1{,}734 \text{ lb. per day}$$

With the same volume of media as in Case 1, the filter loading will be 1,734/2.78 = 624 lb. per acre-ft. per day and the efficiency is

$$\frac{100}{1 + 0.0085\sqrt{624}} = 82.6\%$$

The plant effluent will contain 36.2 p.p.m., and the over-all plant B.O.D. efficiency will be 86.9 per cent.

In order to obtain filter efficiency equal to that of Case 1, the filter media would have to be increased to 1,734 (2.78)/(1,668) = 2.89 acre-ft. (4 per cent).

Case 3. With Snydets and Ground Garbage; No Recirculation

Assume 30 per cent increase in B.O.D. (+ 40 per cent due to garbage, − 10 per cent due to syndets) and that the primary settling efficiency is 30 per cent.

The weight of B.O.D. in the filter influent will be

$$(1.00 - 0.30)\ (1.30)(308)(1)(8.34) = 2{,}338 \text{ lb. per day}$$

With the same volume of media as in Case 1, the filter loading will be 841 lb. per acre-ft. per day, its efficiency 80.2 per cent. The final effluent will have 55.5 p.p.m. B.O.D.; the over-all B.O.D. efficiency will be 86.1 per cent. In order to have the same filter efficiency as in Case 1, the media volume must be increased to 2,338(2.78)/(1,668) = 3.90 acre-ft. (40 per cent).

Case 4. With Syndets and Ground Garbage; Recirculation

Assume the same raw sewage as in Case 3 and the same media volume as in Case 1. To obtain an equivalent 600-lb. per acre-foot loading, and hence equal secondary treatment efficiency,

$$\frac{W}{VF} = \frac{2{,}338}{2.78\,F} = 600$$

and

$$F = 1.40 = (1 + r)/(1 + 0.1\,r)^2$$

where r is the recirculation ratio.

Solving, $r = 0.56$; therefore, a recirculated flow of 0.56 m.g.d. (56 per cent) would have to be supplied.

Modifications in Design to Secure Equal Treatment

In Cases 2, 3, and 4, design modifications necessary to secure the same filter efficiencies have been indicated. These, however, are not sufficient to secure an effluent as good as normal (Case 1). Considerably more drastic

modifications are required to accomplish equal over-all treatment efficiency.

In Case 2, if the effluent is to have a B.O.D. of 34.4 p.p.m. the filter efficiency must be

$$\frac{100[1{,}734 - 34.4(8.34)]}{1{,}734} = 83.45 \text{ per cent}$$

The loading to attain this efficiency may be computed from

$$83.45 = \frac{100}{1 + 0.0085\sqrt{x}}$$

giving

$$x = 543.8 = 1734/V$$

Therefore,

$$V = 3.19 \text{ acre-ft.}$$

This amounts to a $100(3.19 - 2.78)/2.78 = 15$ per cent increase in the volume of filter media.

In a similar manner, it may be shown that in Case 3 to obtain equal overall treatment the volume of the filter must be increased by 211 per cent (to 8.64 acre-ft.)

In Case 4, it will be found that no amount of recirculation, however large, will result in a degree of treatment comparable to the normal.

Bibliographical Notes

1. The most comprehensive and generally satisfying review of syndet experimentation is that of Isaacs (4). Its limitations for American purposes stem mainly from being slightly out-of-date and from reflecting primarily British and European experience.

2. A perceptive and revealing paper by Culp and Stoltenberg (5) contains a brief but useful bibliography.

3. Information on principles of detergency may be obtained in two papers by Gowdy (6)(7), in which the explanation of the chemistry is the best obtainable in the easily available literature; a staff report on the syndet symposium (1951) of the American Chemical Society (3), which treats the chemistry in a more qualitative but satisfactory manner; and an excellent treatment at the right level for many sanitary engineers by Hutchinson (8).

4. The original paper by Rudolfs, Manganelli, and Gellman (9), although based largely on laboratory research, contains much valuable information and a number of shrewd predictions that have since been validated in sewage plant operation.

5. An illuminating investigation of frothing and B.O.D. properties of synthetic detergents is presented by Bogan, Lynch, and Sawyer (10).

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SUBMERGED SLUDGE HEATING AT PHILADELPHIA'S NORTHEAST WORKS *

By Samuel S. Baxter and Herman F. Horlacher

Respectively, Commissioner, and Mechanical Engineer, Design Bureau, Water Department, Philadelphia, Pa.

The history of sewage treatment work has been one of continual change and improvement. Operators, designers, research men, and equipment manufacturers have all contributed to the advance of a process which is at the same time both an art and a science.

As much as is known of the complicated mechanical, hydraulic, biological, and chemical features of sewage treatment, there is still much to be learned and there are still many new methods of treatment which will be developed.

This paper is intended to provide information on a new process of heating sewage sludge as designed, built, and now in operation at the Northeast sewage treatment works in Philadelphia, and as designed and now under construction at the Southwest sewage treatment works. It is believed that this is the first time this process has been used in heating sludge, although it has previous application in other fields.

Like many other new processes in industry, it has been made possible through the combined efforts of many men. Designers and operators on the engineering staffs of the City of Philadelphia and research and development engineers in private industry all contributed to this new development. It should also be remembered that new and better materials have made possible what could not have been done without them in previous years.

Most conventional processes for heating sewage sludge provide for coils or other heating inter-change apparatus in the digestion tank, or in apparatus adjacent to the digesters. Although satisfactory in many cases, this slow heating method had its limitations and drawbacks.

In designing the sludge heating facilities at the Northeast works in Philadelphia, and in preparation for designing the new Southeast and Southwest works in the same city, engineers of the former Bureau of Engineering, Surveys and Zoning, now part of the Water Department, sought a method which would provide more efficient heat transfer than in the existing processes, and the elimination of some of the drawbacks of these processes. Some of the drawbacks were as follows:

1. Inability to maintain the proper temperature control under varying conditions.
2. The problem of sludge caking on coils, with resultant lowering of efficiency and the necessity of cleaning.
3. The problem of corrosion in various parts of the heating system.
4. The problem of inspection and maintenance.

The search for a more direct method of heating led first to the engineers of the local gas utility, and then to the Selas Corporation, which had specialized in gas heating in fields other than sewage treatment.

Description of Units

The procedure adopted is rather simple in its fundamental principle. Raw

* Presented at 25th Annual Conference, Pennsylvania Sewage and Industrial Wastes Assn.; State College, Pa.; Aug. 26–28, 1953.

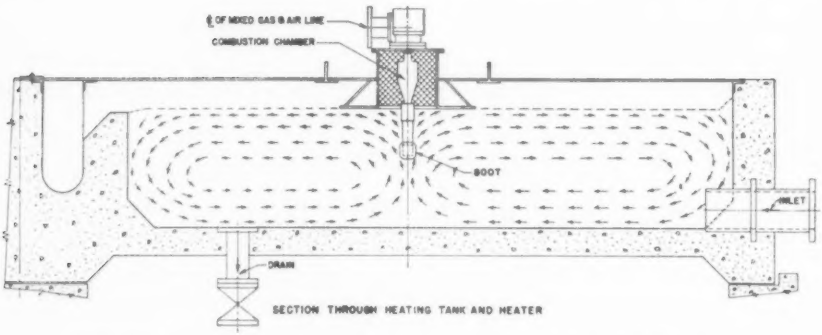


FIGURE 1.—Schematic section of submerged combustion sludge heater.

unheated sludge is passed through a small tank (Figure 1) approximately 12 ft. long by 5 ft. wide by 2 ft. 8 in. deep. At the Northeast works, seven tanks have been installed (Figure 2) and there will be twelve tanks at the Southwest works.

Sewage gas is burned in a combustion chamber on the top of each tank. The hot gases which are the product of combustion are discharged directly into the sludge at temperatures of approximately 2,700° F. and at a high velocity. This results in considerable turbulence of the sludge in the tank and an efficient heat transfer.

The expended gases, at a temperature of approximately 125° F., are carried off in a vent stack and the heated sludge is pumped to the digesters. At the Northeast works, the sludge from the settling tanks is collected in sludge storage tanks and the cold sludge is pumped to the seven heating tanks. Piping is

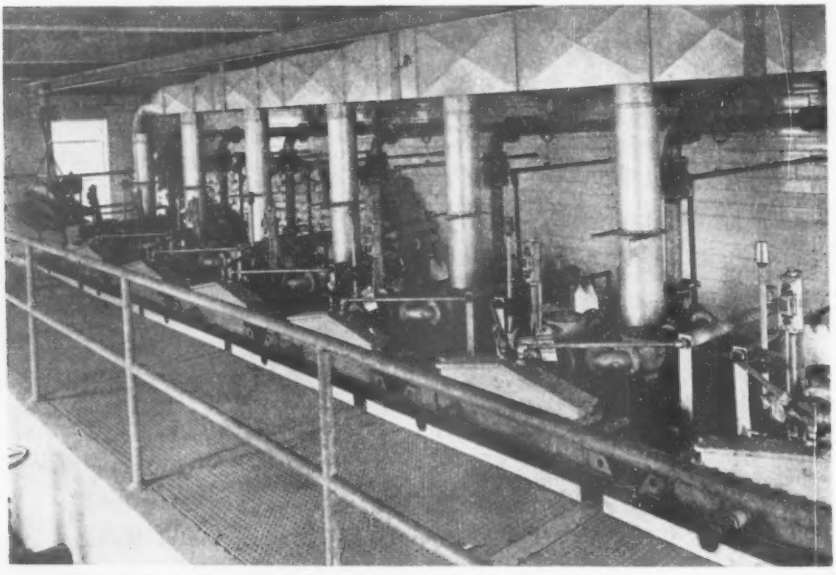


FIGURE 2.—Installation of seven submerged combustion sludge heaters at Philadelphia Northeast sewage treatment plant.

so arranged that the sludge may be delivered to any heater, or any combination of heaters. Heated sludge from all of the heating tanks is collected in a sump approximately 8 ft. wide by 11 ft. 9 in. deep by 12 ft. long. From this sump, the hot sludge is pumped directly to the digesters.

It cannot be emphasized too strongly that, as in many other devices of this type, proper functioning depends upon selection of proper materials and a careful adjustment of mechanical controls.

Gas from the digester is mixed with air in a combustion control unit (Figure 3). This unit automatically fixes the proportions of gas and air and mixes the two. The mixture of gas and air enters the combustion chamber at a pressure of approximately 20 in. w.c. In the ceramic-lined combustion chamber, the gas and air mixture is ignited, with resultant expansion of the gas mixture, which finds its outlet through a diffuser or "boot" extending into the sludge tank. The extreme velocity of the heated gases causes the turbulence described earlier. These velocities are estimated at 25 to 30 ft. per sec.

Evolution of Boot Design

As originally designed, each of the boots contained 640 ⅝-in. diameter holes (Figure 4). In early operations, the extreme heat of the gases produced an effect somewhat similar to that which occurs when the temperature of conventional pipe heat interchangers is raised in excess of 140°. In a conventional heat interchanger, sludge cakes on the piping. In the first period of operation of the new type burner, a small film of sludge was formed across the ⅝-in. holes, which blocked the passage of the gas.

Several methods were tried to overcome creation of this sludge film, including a small wire "jiggler" in each

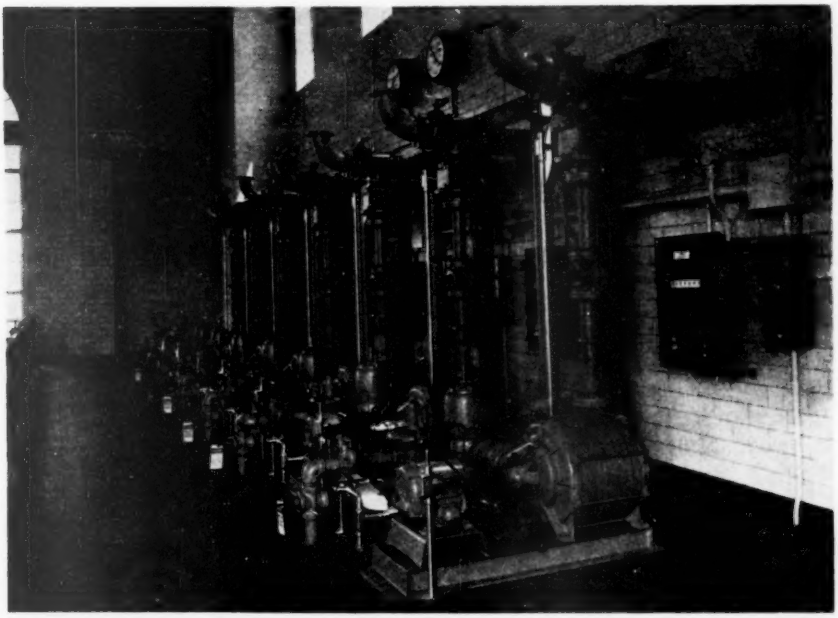


FIGURE 3.—Combustion control units serving submerged combustion sludge heaters at Philadelphia Northeast plant.

FIGURE 4.—Original design of heater "boot" included 640 ⅝-in. holes, was later changed to 32 ½-in. by 1¼-in. slots.

hole and the opposite extreme of one large rectangular slot. Neither of these was successful. The wire jigglers failed to keep the film from forming, and although the boot with one long rectangular slot at the bottom was successful in avoiding formation of the sludge film, "burping" of the escaping gases set up excessive vibration in the aluminum exhaust ducts. The final solution, which has proven satisfactory, is a boot with 32 punched horizontal slots, each ½ in. by 1¼ in. This type boot has been in operation in all the heaters for more than a year.

Unit Operation

At the Northeast works, the average amount of sludge heated is 300,000 g.p.d. In winter, when incoming sludge has a temperature of 50° to 55° F., a maximum of five heaters is in use at one time. In summer, when the sludge temperature is 75° F., only two heaters are required. In practice, the sludge leaves the heaters at a temperature of approximately 110° F.

There has been very little trouble with the heaters as such, but considerable grit settling has been experienced and this has required daily cleaning. It is believed that if grit were properly removed in the grit chambers, there would be little trouble from this source. This problem was solved at the Northeast plant by rearranging the drain pipes from the tanks to permit easy flushing back to the sewer. The routine during the winter of 1952 was to operate five burners and take two heaters out of service daily for cleaning. One of the excellent features of this type of sludge heating is the comparative ease of cleaning. Any material which may be deposited can be readily cleaned by taking the tanks and burners out of operation for one day.

The sludge heaters at the Northeast plant have been quite successful. They

TABLE I.—Data of Sludge Heating Burner Acceptance Test

Time (PM)	Ambient Temp. (° F.)	Combustion Air (cu. ft./hr.)	Fuel Gas[1] (cu. ft./hr.)	Air-Gas Ratio	Total Comb. Mixture (cu. ft./hr.)	Water Flow (g.p.m.)	Water Temp. (° F.)			Water Heated (lb./hr.)	Gas Heat Value (B.t.u./hr.)
							Inlet	Outlet	Rise		
1:25	43	20,600	4,350	4.73	24,950	67	54	114	60	33,400	2,310,000
1:40	43	20,500	4,360	4.70	24,860	64	54	117	63	32,000	2,315,000
1:55	42	20,400	4,400	4.63	24,800	66	54	115	61	33,000	2,335,000
2:10	40	20,500	4,425	4.63	24,925	65	54	116	62	32,500	2,340,000
2:25	44	20,400	4,400	4.63	24,800	65	54	115	61	32,500	2,330,000
2:40	44	20,400	4,370	4.67	24,770	65	54	117	63	32,500	2,315,000
2:55	43	20,400	4,350	4.69	24,750	66	54	116	62	33,000	2,310,000
3:10	43	20,400	4,350	4.69	24,750	65	54	115	61	32,550	2,310,000
3:25	—	20,400	4,375	4.66	24,775	66	54	116	62	33,000	2,320,000

[1] At 530 B.t.u. per cu. ft.

have caused few operating difficulties and have given good digestion temperatures (95° to 100°) with no noticeable odors expelled from the exhaust stack.

Specifications for the units at the Northeast works required the contractor to make a test of the over-all heat transfer efficiency of the burner operating at a guaranteed capacity of 2,300,000 B.t.u. per hr. This test was made prior to the beginning of opera-

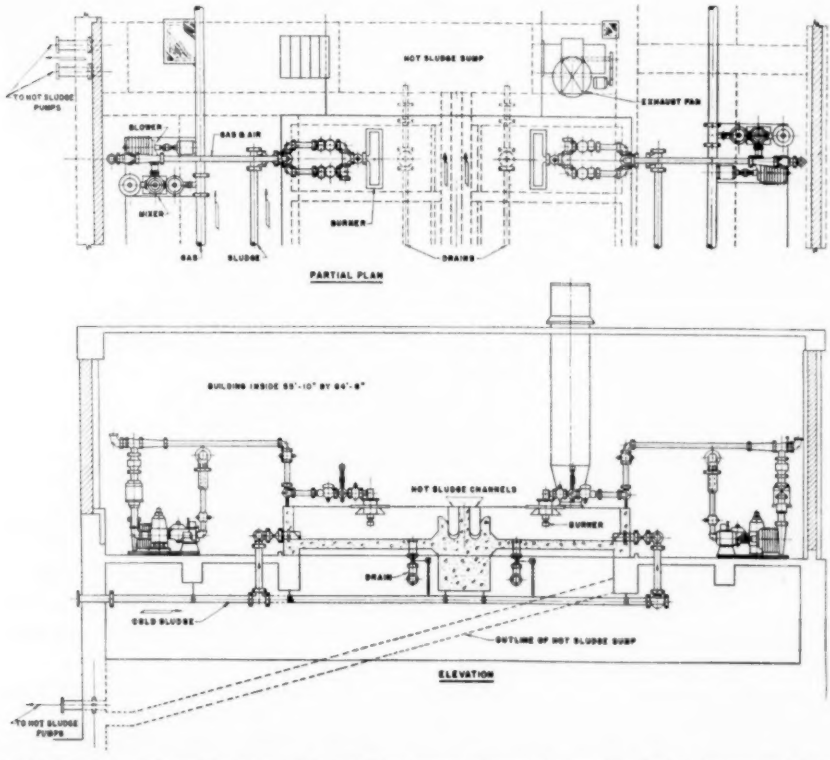


FIGURE 5.—Central location of hot sludge pump allows the twelve sludge heater units to be installed at the Southwest plant in four batteries of three units each.

tion and used water. The average (Table I) over-all thermal efficiency taken at 15-min. intervals during two consecutive hours of operation was 87.3 per cent.

Although exact thermal efficiencies have not been determined, they are carried at about 85 per cent in the Northeast monthly summary statement. This is based on measuring the amount of sludge heated by digester displacement, the amount of gas used as measured by an orifice-type meter, hourly temperature readings on the ingoing and outgoing sludge, and accepting the sewage gas as containing 627 B.t.u. per cu. ft.

The contract price bid for the seven sludge heater units, appurtenant equipment, and piping at the Northeast works, including installation but not including the concrete tanks, was $86,000. An additional $6,000 was required for installation of weirs and inspection holes. Operation of the units at the Northeast works has been successful enough to warrant the specification of this same type of heater at the new Southwest works, which also digests sludge from the Southeast works. Both of these plants are now under construction.

Southwest Units

The heating units at the Southwest works will provide for heating sludge from a total sewage flow of 280 m.g.d., or approximately 840,000 g.p.d. of sludge at 96 per cent moisture. For this installation, twelve burners are being specified.

Based on the operating experience at the Northeast works, several changes have been made in design. The Southwest works installation will have four batteries of three tanks and burner units each (Figure 5). This will allow greater operating flexibility than the "all in one line" installation of the burners at Northeast. Piping has been simplified by this layout. In fact, it has been entirely eliminated on the discharge side of the tanks, the heated sludge flowing over a weir at the effluent end of each tank to be carried to a common sump by concrete channels from each battery of three tanks. The channel and the sump will be entirely enclosed and all gases will be exhausted to atmosphere by an exhaust fan unit.

Another departure from the Northeast design will be the placing of the twelve combustion control units in the same room as the burners. This arrangement also simplifies piping and aids operation materially, as all sludge heating operation will be in one room.

HEMISPHERIC SANITARY ENGINEERING AWARDS

Hemispheric Sanitary Engineering Awards of the U. S. A. Section of the Inter-American Association of Sanitary Engineering were presented recently to Col. Donald Snow, USPHS; Commander Ralph Vanderwecker, U. S. C. G.; Miss Dinora Lopez-Molina, Pan American Sanitary Bureau; and Edward J. Cleary, Chief Engineer and Executive Director, Ohio River Valley Water Sanitation Commission.

Similar awards had previously been presented to Henry W. Foulds, President, The Permutit Company, and to William J. Orchard, recently retired from Wallace & Tiernan Co., Belleville, N. J.

All of the recipients were pioneer workers in the establishment of the Inter-American Association of Sanitary Engineering.

HYDRAULIC BEHAVIOR OF STORM-WATER INLETS

IV. Flow into Depressed Combination Inlets

By Wen-Hsiung Li, Bertram C. Goodell, and John C. Geyer

Assistant Professor of Civil Engineering, Research Associate, and Professor of Sanitary Engineering, respectively, The Johns Hopkins University, Baltimore, Md.

This article presents an analysis of experimental data on the hydraulic behavior of depressed combination inlets. The tests were made using a 1:3 scale model. A method of inlet design has been developed from the knowledge gained from previous studies (1) (2) and checked by application to a variety of depressed combination inlets for which test data were obtained.

The five types of grates used in the investigation are shown in Figure 1. Figure 2 shows the type E frame, which holds any combination of two of the No. 1, No. 2, or No. 3 type grates. The No. 6 grate is designed to go into an E frame from which the center cross member has been removed. The street slope was varied from 1 to 9 per cent, and under each condition the capacities were measured with gutter discharges ranging up to flows which were equivalent to 6 c.f.s. in the prototype.

Test Results

Tests were conducted in the laboratory to study the effects on inlet efficiency of the following factors:

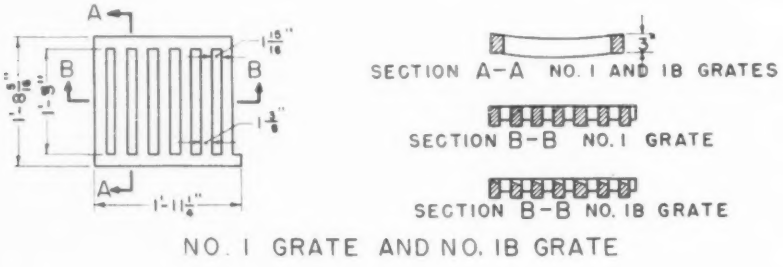
1. Type of grate.
2. Position of grate relative to curb opening.

A single representative prototype depression of $2\frac{1}{2}$ in. was used. The No. 6 grate consists entirely of longitudinal bars. The E and H type inlets, now used in Baltimore City and Baltimore County, have grates or frames with transverse bars or members, the tops of which are flush with the surface of the grate. This type of cross bar reduces inlet capacity. The No. 6 grate, which was designed to eliminate these obstructions, is hydraulically much superior to the No. 1, 2, 3, and H grates. Study of the effect of cross bars indicates that a few small stiffening bars, about 1 in. in diameter, located at or near the bottom of the longitudinal bars of a No. 6 grate have no effect on the hydraulic capacity.

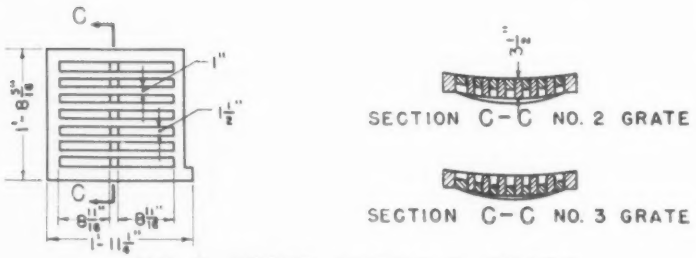
These grates were tested in a depression having the dimensions shown in Figure 2 and were located at various positions relative to curb openings of different sizes. The following conclusions can be drawn from these tests:

1. At any position relative to the curb opening, the grate without transverse bars is the most efficient.
2. Except when the grate is placed upstream from the curb opening, the greater the number of transverse bars the less efficient the inlet.
3. Increase of efficiency is accomplished much more readily by using a more efficient grate than by putting the grate upstream or downstream from the curb opening.
4. Some increase in capacity is obtained by putting the grates having transverse bars either upstream or downstream from the curb opening. When the grate is downstream from the curb opening, some of the water-carried debris will not reach the grate. If that which does reach the grate forms a dam, the capacity of the curb-opening inlet will be increased due to the backing up of water.

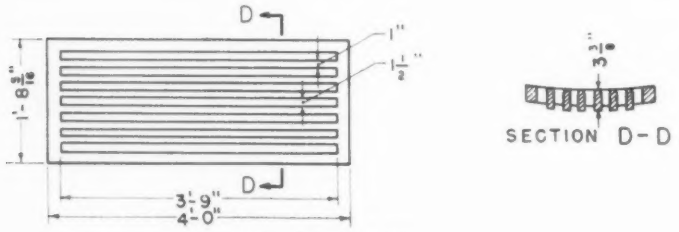
In view of these conclusions, a grate with longitudinal bars (which may, if desired, have a few small cross stiffeners set low in the grate) gives the best hydraulic arrangement when the use of a depressed combination inlet is considered desirable. With this type of grate, and for gutter flows up to 5 c.f.s., inlet capacity cannot be increased by locating the grate either upstream or downstream from the curb opening. For higher flows, and low street slopes,



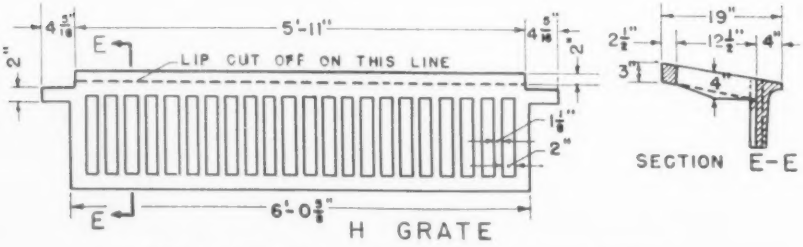
NO. 1 GRATE AND NO. 1B GRATE



NO. 2 GRATE AND NO. 3 GRATE



NO. 6 GRATE



H GRATE

FIGURE 1.—Baltimore storm-water inlet grate designs.

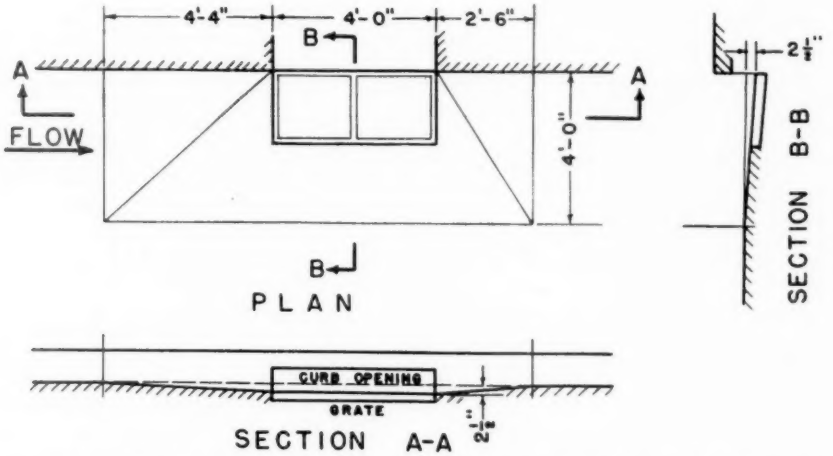


FIGURE 2.—Typical depression for E type Baltimore combination inlet. Full depression extends from end to end of inlet in all cases.

capacity can be increased by a tandem arrangement of the grate and the curb opening. Since street flooding may become a problem before the capacity of this type of inlet is reached, grates would ordinarily be displaced downstream from curb openings only when the reduction in loss of capacity due to

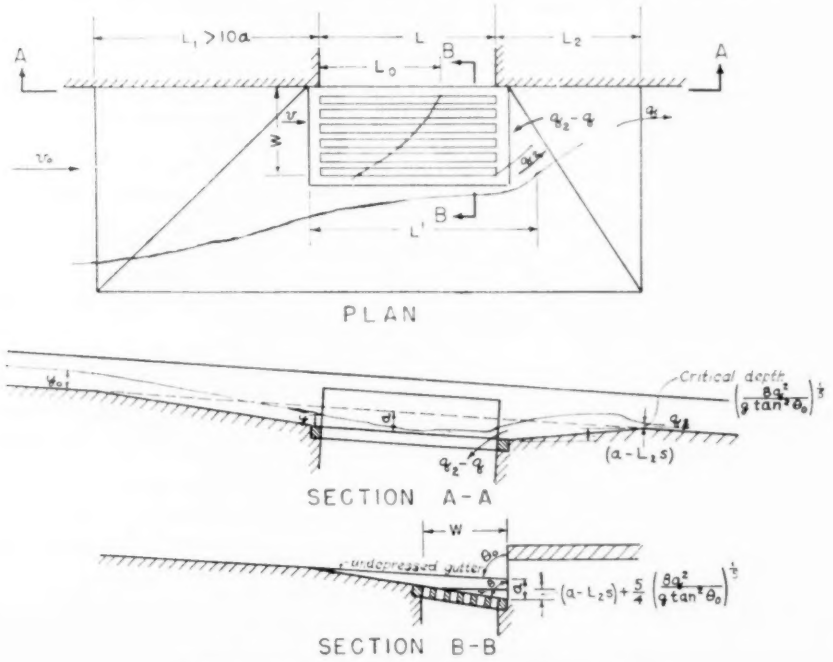


FIGURE 3.—Flow into a depressed combination inlet.

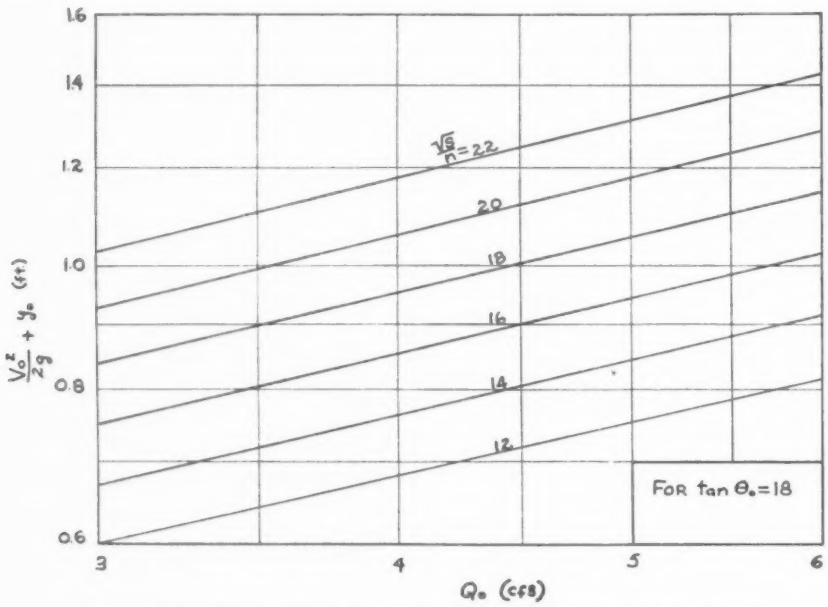


FIGURE 4.—Relationship between the flow in the gutter and its energy per unit weight.

clogging is believed to justify the additional cost. The method of design developed here applies only to depressed combination inlets in which the grate is the same length as the curb opening and is located alongside of it.

Letter Symbols

Figure 3 shows how the letter symbols used apply to the geometry and performance of a depressed combination inlet. These symbols are as follows:

A = cross-sectional area of flow corresponding to y (sq. ft.);
A_0 = cross-sectional area of flow corresponding to y_0 (sq. ft.);
a = depth of depression at curb (ft.);
g = gravitational acceleration (ft. per sec. per sec.);
L = length of grate (ft.);
L_0 = length of grate required to eliminate carry-over flow over grate (ft.);
L_1 = length of upstream transition of depression (ft.);
L_2 = length of downstream transition of depression (ft.);
L' = length of grate required to eliminate the carry-over flow outside the grate, q_2 (ft.);
m = coefficient in Eq. 2;
n = Manning's roughness coefficient for the gutter;
Q = flow into the inlet (c.f.s.);
Q_0 = flow in gutter (c.f.s.);
q = carry-over flow past the inlet (c.f.s.);
q_2 = carry-over flow outside the last slot of grate (c.f.s.);
R = ratio of the total width of clear spaces between bars to the width of the grate;
S = street grade (ft. per ft.);
V = Q_0/A (ft. per sec.);
V_0 = velocity of flow in gutter = Q_0/A_0 (ft. per sec.);
w = width of grate (ft.);
y = depth of flow at upstream end of grate (ft.);
y_0 = depth of flow in gutter (ft.);

θ = angle between vertical and depressed gutter surface;
θ_0 = angle between vertical and undepressed gutter surface.

Method of Design

The following method is suggested for the design of depressed combination inlets having longitudinal bar grates alongside curb openings of equal length (see Figure 2). Part I of this series (1) presents an analysis of the hydraulic behavior of undepressed combination inlets. It was shown that the capacity of an inlet depends, among other factors, on the velocity, v, and the depth, y, of the approaching flow. In the undepressed inlet the values of v and y are equal to v_0 and y_0 of the gutter flow, respectively. In the case of depressed inlets, the value of v and y at the upstream end of the grate must be computed. A method of using the equation for energy per unit weight, E, to find these quantities for depressed curb inlets was presented in Part II of this series (2). For cases where $L_1 > 10a$, the equation involved is

$$E = \frac{Q_0^2}{2g\,A^2} + y = \frac{Q_0^2}{2g\,A_0^2} + y_0 + a \quad . . (1)$$

It was also demonstrated that the solution of Eq. 1 may be facilitated by graphs similar to Figures 4 and 5. If the values of v and y have been computed, the formulas presented in Part I can be used for calculating the capacity of depressed combination inlets.

Water can flow past a grate inlet in three ways, as shown in Figure 3. These are:

1. Flow between the curb and the first slot of the grate, which is generally very small and can be ignored in practice.
2. Flow outside the last slot, q_2.
3. Flow over the grate itself.

To eliminate the last item, it is necessary for the length of grate, L, to be equal to or greater than the length L_0

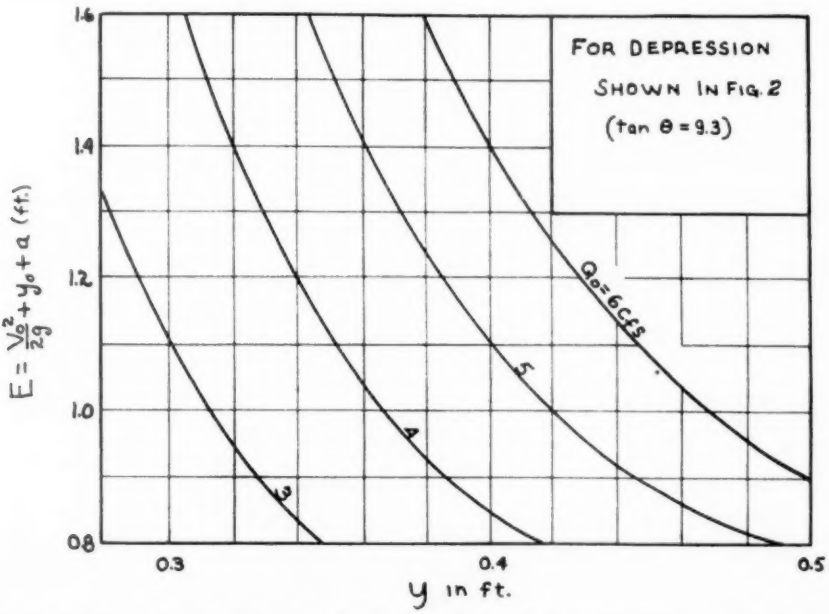


FIGURE 5.—Relationship between depth of flow onto grate and energy per unit weight.

given by

$$L_0 = m\,v\sqrt{\frac{y}{g}} \quad \ldots\ldots\ldots (2)$$

The value of m depends on various factors. For combination inlets with a bar width equal to or slightly less than the clearance between bars, $m = 3.3$ if no large transverse bars are flush with the grate surface, and $m = 6.6$ if several transverse bars are present. If the length of grate, L, is much less than the length, L_0, required to prevent carry-over across the grate, the inlet will become very inefficient. Only grates with $L \geq L_0$ are considered here.

To eliminate the carry-over flow q_2 past the outside slot, the length of the grate, L, should be equal to or greater than a length L' given by

$$L' = 1.2\,v\tan\theta\sqrt{\frac{y - \dfrac{w}{\tan\theta}}{g}} \quad \ldots (3)$$

If the length of grate, L, is less than L', the carry-over flow, q_2 is given by

$$q_2 = \tfrac{1}{4}\,(L' - L)\sqrt{g} \times \left(y - \frac{w}{\tan\theta}\right)^{3/2} \quad \ldots (4)$$

Due to the ponding at the downstream end of the depression, part of q_2 will flow into the lower end of the grate and into the curb opening. The net carry-over flow, q, from the inlet will thus be less than q_2, as indicated in Figure 3. Since in designing an inlet only small values of q are of practical interest, the following approximate method is suggested for finding q.

As gutter flow is invariably supercritical for street slopes greater than 1 per cent, it can safely be assumed for cases where $(a - L_2 S) > 0$ that the depth at the downstream end of the depression is equal to the critical depth, as shown in Figure 3. Since the

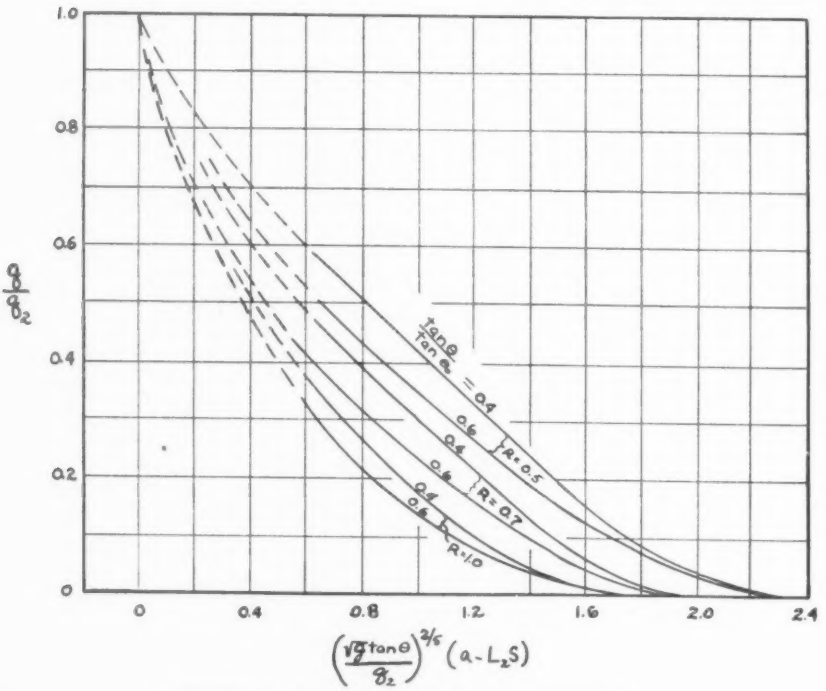


FIGURE 6.—Solutions of Eq. 5 for carry-over flow.

velocity head at critical flow in a triangular channel is equal to $\frac{1}{4}$ of the critical depth, the total depth of the pond over the grate for cases with comparatively large $(a - L_2 S)$ may be assumed to be

$$(a - L_2 S) + \frac{5}{4}\left[\frac{8 q^2}{g \tan^2 \theta_0}\right]^{1/5}.$$

Using this depth, the discharge into the lower end of the inlet, $(q_2 - q)$, may be approximated by the discharge formula for a triangular weir with the conventional value of 0.6 as the coefficient of discharge, or

$$q_2 - q = 0.226\, R \sqrt{g} \tan \theta \left\{(a - L_2 S) + \frac{5}{4}\left[\frac{8 q^2}{g \tan^2 \theta_0}\right]^{1/5}\right\}^{5/2} \quad . . (5)$$

where R is the ratio of total width of clear openings to width of grate, usually about 0.5 to 0.6. The solution of Eq. 5 is shown graphically in Figure 6.

Illustrative Example

As an illustrative example let it be required to find the capacity of the combination inlet with depression shown in Figure 2 and the grate shown in Figure 3. The gutter flow, Q_0, is 5 c.f.s., the street grade is 5 per cent, and the roughness coefficient, n, for the gutter is 0.013.

To Find y *and* v

The depth of gutter flow, y_0, may first be computed by using Manning's formula, and the depth, y, is then computed from Eq. 1. Graphs similar to Figures 4 and 5 can be used to find y as follows:

The cross slope of the street is $\tan \theta_0 = 18$, for which Figure 4 has been constructed. With $\frac{\sqrt{S}}{n} = \frac{\sqrt{0.05}}{0.013} = 17.2$, and $Q_0 = 5$ c.f.s., Figure 4 gives $\frac{v_0^2}{2g} + y_0 = 1.008$ ft. The depression depth, a, in this case is $2\frac{1}{2}$ in., or 0.208 ft.; therefore, $E = \frac{v_0^2}{2g} + y_0 + a = 1.216$ ft. Figure 5 has been prepared for the depression in question. With $E = 1.216$ ft. and $Q_0 = 5$ c.f.s., Figure 5 gives $y = 0.382$ ft. Thus $A = \frac{1}{2} y^2 \tan \theta = \frac{1}{2} \times 0.382^2 \times 9.3 = 0.68$ sq. ft., and $V = Q_0/A = 5/0.68 = 7.4$ ft. per sec.

Check on L_0

For the longitudinal bar grate, use $m = 3.3$ in Eq. 2. Thus,

$$L_0 = 3.3 \times 7.4 \times \sqrt{\frac{0.38}{32.2}} = 2.66 \text{ ft.}$$

Since L_0 is less than the length of grate, L, of $3\frac{2}{3}$ ft. there will be no carry-over flow over the grate itself.

To compute q_2

From Eq. 3, $L' = 1.2 \times 7.4 \times 9.3 \sqrt{\frac{0.382 - \frac{1.67}{9.3}}{32.2}} = 6.92$ ft.

From Eq. 4, $q_2 = \frac{1}{4}(6.92 - 3.67) \sqrt{32.2} \left(0.382 - \frac{1.67}{9.3}\right)^{3/2} = 0.422$ c.f.s.

To find q

Here $\left(\frac{\sqrt{g} \tan \theta}{q_2}\right)^{2/5} (a - L_2 S) = \left(\frac{\sqrt{32.2} \times 9.3}{0.422}\right)^{2/5} (0.208 - 2.5 \times 0.05) = 0.573$, $R = \frac{1\frac{1}{2}''}{1\frac{1}{2}'' + 1''} = 0.6$, and $\frac{\tan \theta}{\tan \theta_0} = \frac{9.3}{18} = 0.516$. From Figure 6 or from Eq. 5, $\frac{q}{q_2} = 0.5$. Thus, $q = 0.5 \times 0.422 = 0.211$ c.f.s., and $\frac{q}{Q_0} = \frac{0.211}{5} = 4\%$. If other values of $\frac{q}{Q_0}$ are desired, the computations may be repeated with other values for the length of grate.

Computed values of $\left(1 - \frac{q}{Q_0}\right) = \frac{Q}{Q_0}$

TABLE I.—Computation of Inlet Capacity

Arrangement of inlet: As shown in Figure 3.

Grate: Type No. 6 in Figure 1.
$m = 3.3$
$L = 3$ ft. 8 in.
$w = 1$ ft. 8 in.
Bar width = 1 in.
Clearance between bars = $1\frac{1}{2}$ in.
$R = 1\frac{1}{2}/(1 + 1\frac{1}{2}) = 0.6$

Gutter: $n = 0.013$
Crown: $\tan \theta_0 = 18$
Depression: Depth $a = 2\frac{1}{2}$ in.
$L_1 > 10a$
$L_2 = 2.5$ ft.
$\tan \theta = 9.3$

Street Slope	Gutter Flows,[1] Q_0 (c.f.s.)	Computed Values					Observed Q/Q_0
		L_0	L'	w_c	q	Q'/Q_0	
0.01	5.0	1.86	4.61	0.223	0.020	1.00	1.00
	5.5	1.90	4.87	0.312	0.050	0.99	0.98
	6.0	1.95	5.10	0.404	0.085	0.99	0.96
0.05	5.0	2.66	6.92	0.422	0.211	0.96	0.97
	5.5	2.75	7.33	0.531	0.271	0.95	0.95
	6.0	2.82	7.76	0.656	0.354	0.94	0.92
0.09	5.0	3.08	7.80	0.404	0.404	0.92	0.95
	5.5	3.20	8.23	0.490	0.490	0.91	0.93
	6.0	3.28	8.78	0.620	0.620	0.90	0.90

[1] Values used in model testing the inlet. The calculated and observed values of the ratio of inlet capacity to these gutter flows appear in the last two columns.

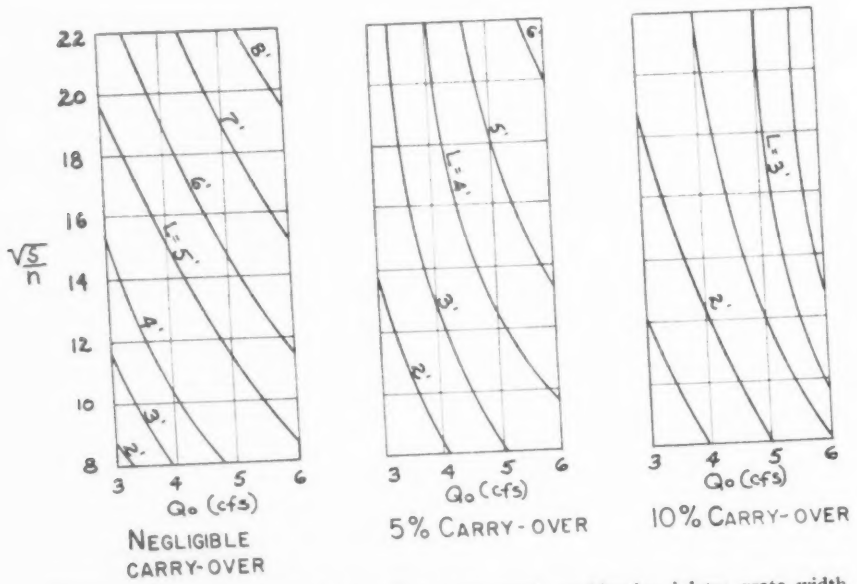


FIGURE 7.—Required length of grate for depressed combination inlets: grate width 20 in., depression width 4 ft., street crown 1: 18, grate bars parallel with curb and no major cross bars in grates less than 4 ft. long.

are listed in Table I for comparison with values obtained from the model tests. The validity of this method of design is supported by the agreement between computed and observed values.

Figure 7 shows the required lengths of grate under different field conditions for combination inlets with $2\frac{1}{2}$-in. depressions in a street of 1:18 crown. These graphs are presented for the purpose of showing approximately the required length of grate for what may be considered an average field condition. If the actual depression design and street crown is quite different from this, independent computation must be made to determine the required length. As can be seen in Figure 7, when no carry-over flow is allowed a depressed combination inlet with one 4-ft. grate having no large obstructing cross members will, at $\frac{\sqrt{S}}{n} = 13$, take 3.5 c.f.s., and with two such grates, or the equivalent of an 8-ft. grate with a transverse bar, the inlet can take about 8 c.f.s. If 10 per cent carry-over flow is permitted, the inlet with one grate will take about 6.5 c.f.s.

Comparison with Other Inlets

When a longitudinal bar grate is used the depressed combination inlet is the most efficient type among those reported upon in this series of articles. In places where gutter depressions are not desirable, as is the case for inlets along express highways, or along urban streets where the lane close to the curb is used for traffic, curb inlets with deflectors may be used in steep streets and undepressed combination inlets in streets of mild slopes.

Acknowledgments

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Industrial Wastes

INDUSTRIAL WASTE GUIDE—BLAST FURNACE DEPARTMENT OF THE STEEL INDUSTRY

By Hayse H. Black and Gerald N. McDermott

Chief and Sanitary Engineer, respectively, Industrial Wastes Section, Robert A. Taft Sanitary Engineering Center, USPHS, Cincinnati, Ohio

The steel industry in the United States reported 258 blast furnaces as of December 31, 1952, of which 247 were operating. These blast furnaces were located at 87 establishments in 18 states, but more than 50 per cent were in the states of Ohio and Pennsylvania. Production of pig iron and ferro-alloys for recent years was as follows:

Year	Production (1,000 tons)
1940	47,399
1945	54,919
1948	61,043
1949	54,174
1950	65,438
1951	71,277
1952	62,150

The most significant liquid waste from blast furnace operations originates with wet scrubbing of the blast furnace flue gas. The principal pollutional characteristic of the flue gas wash water is suspended solids, which consist of fine particles of ore, coke, and limestone. Total water requirements of the industry for cleaning blast furnace gas have been estimated at 500 m.g.d. Untreated gas washer wastes for one year's operation of blast furnaces in the United States, at the 1952 production level, contain approximately 1,500,000 tons of suspended materials.

Manufacturing Process

The first of three distinct steps in the manufacture of steel is the production of pig iron from the ore in blast furnaces. This is followed by purification of the pig iron and adjustment of certain constituents in open-hearth furnaces, Bessemer converters, or electric furnaces. Finally, the steel is shaped to the desired product by means of rolling mills. These three operations may be carried out at one integrated plant or at separate locations. This guide is concerned only with the liquid wastes of the blast furnace department.

Pig Iron Production

The blast furnace is a vertical, quasi-cylindrical structure, ranging from 65 to 106 feet high and 15 to 28 feet in diameter. In operation, it is maintained full of a mixture of ore, coke, and limestone, and functions continuously for months at a time. The materials are admitted at the top of the furnace and a large volume of air, preheated to between 1,000 and 1,500° F., is blown in near the bottom. Combustion of the coke produces carbon monoxide, which subsequently removes oxygen from the ore. Two charcoal-burning furnaces are known to be in existence. The uncombined iron melts at the high temperature (2,900 to 3,600° F.) reached in the furnace and flows into a pool 3 or 4 ft. deep at the bottom of the furnace. The limestone or other fluxing agent performs a purifying or purging function by rendering fluid, at furnace temperature, the

rock and undesirable elements of the ore and the ash of the fuel. This material, termed "slag," more than 90 per cent of which is made up of oxides of calcium, silica, aluminum, and magnesium, collects on the top of the iron pool at the bottom of the furnace.

The molten iron and slag are removed separately at regular intervals by opening tap holes at appropriate levels in the furnace. The pig iron is drained to a ladle and delivered in a molten condition to steel-making operations or to a series of molds on a slowly moving endless chain. The iron solidifies in the molds forming into bars, known as "pigs," which weigh from 50 to 100 lb. The "pigs" may be stored or shipped for later charge to steel-making furnaces, or remelted and treated for production of castings. Blast furnaces vary in capacity from a few hundred to 1,750 tons of pig iron per day.

Blast Furnace Gas

Gas liberated within the blast furnace, including the nonreactive constituents of the air, amounts to about 110,000 cu. ft. per ton of pig iron produced (measured at standard conditions, 60° F. and 30 in. of mercury). It carries from 4 to 20 grains of particulate matter and between 7 and 50 grains of water vapor per cubic foot. The temperature of the gas leaving the top of the furnace may be as low as 300° F. and as high as 600° F.

Blast furnace gas contains sufficient carbon monoxide to give it a fuel value of approximately 90 B.t.u. per cubic foot. About one-fourth of the gas is burned in stoves where the furnace air is preheated. The remainder is used for such purposes as generation of steam, firing of coke ovens, and for metallurgical heating.

Gas Cleaning

Prior to use of the gas, removal of the dust is accomplished to prevent fluxing of refractories, accumulation of deposits in conduits and gas-burning equipment, and erosion of facilities. The particle size of this ore-coke-limestone dust ranges from 0.1 to 0.000002 in. in diameter. The degree of cleanliness for various gas uses has not been standardized. Conventional practice is to clean blast furnace gases to dust contents below 0.1 and as low as 0.002 grain per cubic foot. Plants may clean to a high degree only a portion of the gas. Non-combustible solids remaining in the gas contribute to air pollution unless provision is made for their removal from stacks of units burning the gas.

Recovery of valuable materials from the dust is an additional incentive to cleaning. Iron in the dust is recovered by recharging to the furnace. The carbon of the dust contributes heat to the sintering process. A method for recovery of iodine and potassium chloride from blast furnace dusts was developed in Germany during wartime search for independent supplies (1).

Methods employed for separating dust from the gas are numerous. A thorough discussion of principles of operation and description of blast furnace gas cleaning plants is given by Jennings (2), who suggests possible lines of improving separating power and mechanical efficiency and draws attention to the lack of data on this subject, particularly on water-spray systems and the behavior and nature of blast furnace dust. In general, the operation consists of three stages—namely, dry dust separation in dust catchers, primary cleaning in wet washers, and final cleaning by wet-type electric precipitators or disintegrators. Primary dry cleaners may be employed in place of wet cleaners, and final cleaners may be dry-type electric precipitators.

(a) Dustcatcher—The Dustcatcher is commonly of the momentum type (Figure 1). It is a vertical cylindrical shell, about 30 ft. in diameter, which

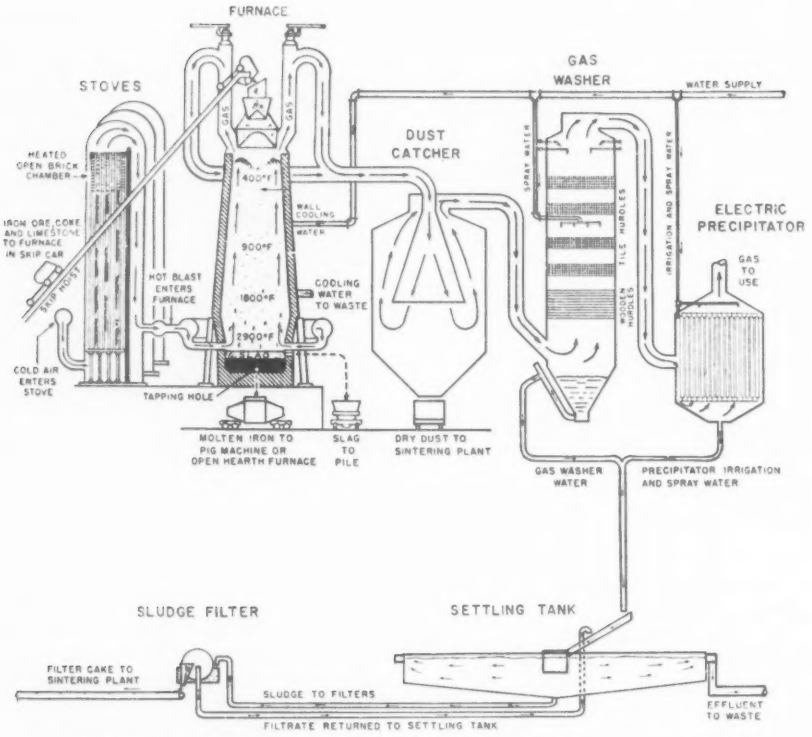

FIGURE 1.—Flow diagram for blast furnace and solids recovery system.

is fitted with an inverted conical bottom and a cone-shaped top. The gas enters the dustcatcher through a vertical pipe that extends into the lower portion. In the latest designs, the pipe is flared outward toward the bottom. The gas passes around the bottom of the pipe and up to an outlet near the top. Initial momentum and gravitational force carry the dust to the bottom of the catcher, from which it is continuously removed by a pug mill. These units remove from 40 to 85 per per cent of the dust. Leaving the dustcatcher, the gas contains between 0.5 and 5 grains of dust per cubic foot.

(b) Primary Wet Washers—Primary wet washers are cylindrical steel towers, with conical bottoms and tops, in which the gas is made to pass through water sprays or over extensive wet surfaces. The towers are ordinarily 11 to 20 ft. in diameter by 40 to 70 ft. high. Gas enters the tower at a point near the bottom and passes out near the top, moving counter to the falling water sprays. Primary washer types include stationary-spray towers, revolving-spray towers, Feld washers, baffle towers, spray fans, and combinations of these types.

The stationary-spray tower (Figure 1) is used most. It contains three or more banks or layers of contacting media, such as tile or wood. Above the layers are water sprays which cover the cross-section of the washer with water drops. The layers of media split up the rising gas and tend to prevent channeling and the wetted surfaces present extensive surface area to the moving gases. It is claimed that spiral-shaped

tile with parallel passages constitute the most effective contacting layers (3). Dust particles which contact the water drops or the wetted surfaces are washed out of the tower with the spray water through a trapped outlet at the bottom. Cooling of the gases causes a condensation of moisture. This condensation is considered to take place in part on dust particles and thus aids in their removal.

Many Feld washers remain in use. Spaced uniformly along the axis of the tower of the Feld washer are 5 to 7 inverted frustrums of cones which are rotated rapidly. They dip into a water tray, from which they pick up water and spray it outward over the cross-section of the tower. Baffles guide the water back into the tray for re-use, the excess water spilling into the next tray below.

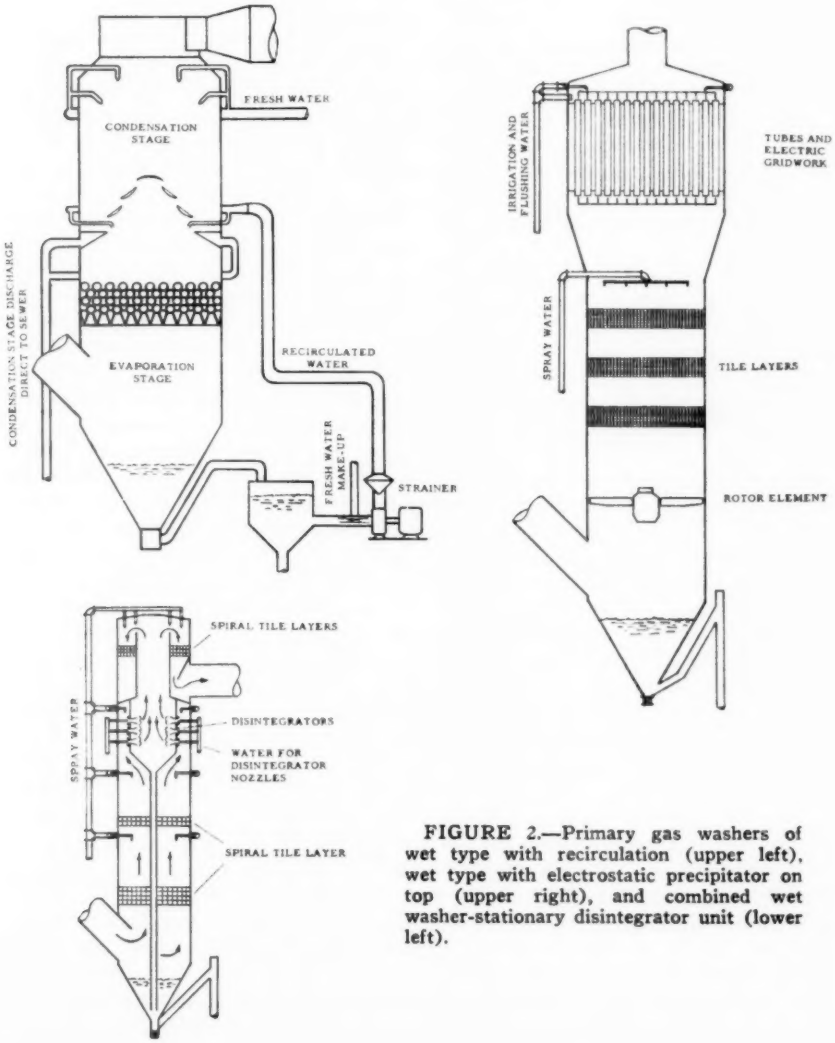

FIGURE 2.—Primary gas washers of wet type with recirculation (upper left), wet type with electrostatic precipitator on top (upper right), and combined wet washer-stationary disintegrator unit (lower left).

Several different designs of wet washers are presented in Figure 2. Two of the structures include final cleaners. All are designed to employ some of the following principles:

1. Subdivision of the gas into small streams.
2. Turbulence of flow of gas streams.
3. Contact of gas with numerous water drops and extended wetted areas.
4. Wetting by water vapor condensation.

Gas leaving primary wet washers usually contains 0.05 to 1.0 grain of dust per cubic foot.

(c) Final Cleaners, Wet Type—Final cleaning is accomplished by any one of the following: electric precipitators, high-speed disintegrators, Theisen disintegrators, and stationary disintegrators (14).

In precipitators, the primary cleaned gas is forced to pass through narrow channels or ducts, across which a high-tension electric field is maintained. A potential of unidirectional current of from 30,000 to 80,000 v. causes a corona discharge from one electrode, producing a large number of charged gas ions. The gas ions attach themselves to the dust particles, which in turn become charged. Unlike electrostatic charges attract; therefore, the dust particles travel to the oppositely charged electrode. In most precipitators, the collecting electrode is a vertical tube 8 or 12 in. in diameter, or it may be of parallel steel plates, through which the gas is forced upward or sideways. The charged electrodes are rods placed midway between the plates or in the center of the tubes.

The dust reaching the collecting electrode, tube or plate, is caught and carried away by a thin film of water continuously flowing over the surfaces. Water is introduced at the top of the tube or plates, so that it overflows evenly down the inside of the tube or the faces of the plates. At intervals of 1 to 12 hr. additional water is sprayed into the precipitator for a few minutes to provide a heavy flush. In recent installations, the precipitator has been superimposed on the wash tower to economize on space.

The Theisen disintegrator is a multi-bladed fan that intimately mixes water, introduced through small jets, with the gas forced through the device in the opposite direction. The rotary disintegrator is somewhat similar but is smaller and revolves more rapidly. It consists of a squirrel-cage rotor mounted in a casing. Vanes mounted on the heads of the cage reduce the pressure drop through the machine and force the incoming gas through the rotating bars of the cage, upon which water is sprayed. The rapidly revolving cage gives the gas and water an intensive mixing as they flow through the spaces.

The stationary disintegrator consists of a Venturi-shaped tube with throat about 4 in. in diameter, in which is placed a high-pressure, fine spray, water nozzle (Figure 3). The gas enters on all sides of the water nozzle; the mixture of gas and water then impinges on a dish-shaped baffle.

Gas cleaned by the final methods described may be expected to have a dust content between 0.002 and 0.02 grain per cubic foot. Moisture of the gas is reduced through cooling by the wash-

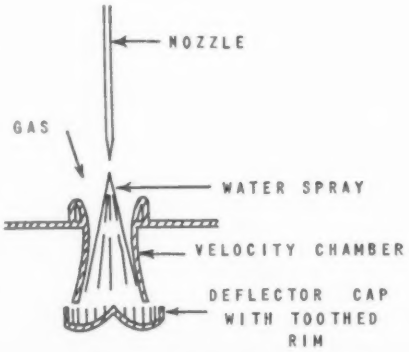

FIGURE 3.—Schematic drawing of stationary disintegrator.

ing phases of gas cleaning, from its original range of 7 to 50 grains down to 1 to 15 grains per cubic foot. The temperature is lowered from the initial temperature of 300° to 600° F. to a temperature between 55° and 95° F.

(d) Primary Dry Cleaners—Primary dry cleaners include cyclone separators, centrifugal machines, and metallic-wool pad filters. Cyclone separators are used in Europe in place of dust-catchers at some plants, and both in the United States and abroad as supplemental cleaners following the dust-catcher. The cyclone separator is a cylindrical tank with conical bottom. The gas enters the tank tangentially near its top. Centrifugal action plus gravitational force causes dust particles to be thrown to the sides of the tank and to settle to the bottom. Centrifugal machines and metallic-wool pad filters have been tried for cleaning following the dustcatcher, but have not met with wide adoption.

(e) Secondary Dry Cleaners—Secondary cleaners of the dry type include bag filters and dry-type Cottrell precipitators. The bag type, sometimes called the Halburg Beth filter, consists of a number of fabric filter bags or "socks." The lower (open) ends of the bags are fastened to a plate, forming the division wall between the dirty and clean gas chambers. The gas passes through the socks from the inside, forming a film of dust on the fabric, which acts as the filtering medium. When the film of dust becomes too thick, the exit end of the chamber is closed, thereby shutting off the gas flow. The sock is then shaken or vibrated to drop the excess dust into a collecting hopper. The socks are stiffened by hoops to prevent their collapse. One difficulty in these units has been the breakdown of the fabric in the high temperatures encountered with hot blast furnace gas. If condensation occurs, wet dust deposits on the sock and cannot be dislodged readily, thereby retarding gas flow. A recent development, tested on pilot-plant scale, employing filters made of asbestos and glass fiber and a new design for mounting the bags, is claimed to overcome these difficulties (4).

The dry-type electric precipitator operates on the same principle as the wet type, but differs in construction. The collecting electrodes are slabs of reinforced concrete. Periodically, each unit is taken out of service to permit the dust on the collecting electrode to fall into a hopper below. In this type, the dust is detached from the collecting electrode by suspended chains, which are used as scrapers.

Top Pressure Operation

At times of high demand, most furnaces are blown at as high a rate as possible consistent with reasonable loss of flue dust, acceptable efficiency, and regularity of operation. One of the limiting factors governing the rate of iron production of a furnace is the quantity of dust carried out in the gas. The tendency of the gas to carry dust, provided other factors are constant, is determined by the velocity of the gas. A relatively recent development has been the restriction of gas outlets in order to create pressure in the blast furnace. This results in reduced velocities of gas when comparing similar masses. An increase in the average static pressure of gas in a blast furnace decreases the volume and increases the density of the gas. This permits a greater mass of air to be blown at decreased velocities through the furnace; consequently more pig iron can be produced. It follows that at any particular top pressure it would be possible to increase the volume of air blast to the point where critical velocities regarding flue dust would prevail just as in normal pressure operation. For example, computations show that identical velocities of air through a furnace would prevail when operating at ordinary pressure and using 85,000 c.f.m. of air and when operating at 10 p.s.i.

TABLE I.—Blast Furnace Gas Wash Water Pollutional Constituents and Volume per Ton of Pig Iron Produced

Plant No.	Special Feature of Plant	Flow (gal.)	Total Susp. Solids (lb.)	Vol. Susp. Solids (lb.)	Iron, as Fe (lb.)	Cyanide, as CN (lb.)
1	Sintering	4,730	26	3.9	17	0.050
2a	Top pressure	3,250	46	5.1	16	0.021
2b	None	2,280	63	6.1	22	0.013
3	None	3,300	42	5.2	16	—

top pressure while using 120,000 c.f.m. of air, both measured at normal temperature and pressure. Thus, this top pressure permits an increase of more than 40 per cent in the mass of air in the blast with no increase in velocity. Any intermediate blast rate when using top pressure will result in reduced velocities and reduced dust concentration in the gas.

Raw Materials and Products

Raw Materials

Principal raw materials for the production of 1 ton of pig iron are approximately as follows:

Iron ore	3,600 lb.
Coke	1,900 lb.
Limestone	900 lb.
Air	7,000 lb.

Products

The product of the blast furnace is pig iron. It contains impurities such as carbon, sulfur, silicon, and manganese. The content of these substances must be reduced for conversion of the pig iron to steel.

Blast furnace slag is used for several purposes. Slag processing plants operating in the United States processed approximately 27,000,000 tons in 1952. Most of this material is used for railroad ballast, cement, concrete aggregate, highway construction, and landfill. A substantial tonnage is used to manufacture mineral wool and a small amount is used in fertilizers because of its high phosphorus content.

Hot slag may be used to evaporate pickle liquor. A method has recently been developed in which pickle liquor is neutralized with granulated slag.

Blast furnace gas, although of low B.t.u. content, is of value particularly for use in the steel plant.

Volumes and Character of Wastes

Blast Furnace Gas Wash Water

(a) Combined Wastes—Combined wastes are those originating in the gas washers and electric precipitators. Water is used in the washers for directly removing dust particles from the gas and in precipitators for washing dust from collecting electrodes, as previously described under "Manufacturing Process." Data obtained from

TABLE II.—Blast Furnace Gas Wash Water Characteristics

Plant No.	Special Feature of Plant	Total Solids (p.p.m.)	Diss. Solids, Total (p.p.m.)	Susp. Solids		Iron, as Fe (p.p.m.)	Cyanide, as CN (p.p.m.)	pH Range of Composite Samples	Alkalinity, as $CaCO_3$	
				Total (p.p.m.)	Vol. (p.p.m.)				Water Supply (p.p.m.)	Gas Wash Water (p.p.m.)
1	Sintering	686	16	670	100	440	1.28	7.4–7.9	215	290
2a	Top pressure	1,850	140	1,710	188	600	0.79	7.3–8.6	45	141
2b	None	3,470	140	3,330	319	1,180	0.66	7.5–9.4	45	147
3	None	1,920	380	1,540	191	575	—	7.1–9.4	—	—

sampling and analysis of this waste at three plants are presented in Tables I and II (5). The data presented in these tables are for the waste prior to any treatment. The concentrations and quantities, except where noted, are net figures; that is, deductions for materials in the water supplies have been made.

The concentrations of dust in the wash water are dependent upon the dust contained in the gas, the efficiencies of the dry dustcatcher and of the washer, and the volume of water used. The plants studied employed dry dustcatchers, gas washers of both the scrubbing tower and the spray tower types, and electric precipitators of the tube type. These units differed considerably in details of construction at the various plants and even at the same plant. Special features influencing dust production are indicated in the tables. One furnace was operating with lower than normal gas velocities in the furnace and the gas cleaning plant by virtue of top pressure design. Plant No. 1, which utilized fine ore, operated a sintering plant for all fine ore, dust, and mill scale of the charge.

These results show that a considerable amount of the suspended material in the wastes is iron. The quantity of iron in solution is insignificant. Volatile suspended solids are considered to consist essentially of coke dust, although the presence of carbonate compounds is recognized as a source of error in this determination. Increases in pH and alkalinity values reflect the limestone in the furnace charge. Cyanide was present in relatively low concentrations.

Data recorded in Table III reveal substantial quantities of phenolic-type materials in blast furnace gas wash water at plants using coke that has been quenched with ammonia still and benzol plant wastes (15). It is of particular interest that the results for Plant No. 1, where coke was quenched with dephenolized ammonia still waste, were of the same order as those for plants quenching coke with the more concentrated phenolic wastes. Plant No. 2 used coke which had been quenched with river water containing an average of 60 p.p.b. phenol. It is evident from these data that blast furnace gas wash water can be a significant source of phenol. Further research is needed to demonstrate the effect of extended storage and moisture content of the coke on phenol carry-over into the gas wash water.

TABLE III.—Phenols in Blast Furnace Gas Wash Water

Plant No.	Source of Water for Quenching of Coke	Phenols (p.p.m.)	Phenols per Ton of Pig Iron (lb.)
1	Dephenolized ammonia still wastes, benzol plant wastes, and fresh water	0.72	0.028
2a	Grossly polluted river water	0.03	0.0008
2b	Grossly polluted river water	0.07	0.0013
4	Ammonia still and benzol plant wastes	0.706	0.0243
5	Ammonia still and benzol plant wastes	0.411	0.0194
6	Ammonia still and benzol plant wastes	0.321	0.0231
7	Ammonia still and benzol plant wastes plus additional wastes from a nearby plant	3.822	0.0819

A significant fluoride content in blast furnace gas wash water has been reported at a steel mill using ore with a high fluoride content (16). Fluorides were determined in blast furnace gas wash water from each of five plants using ores from Minnesota and Michigan. Results from the latter studies (Table IV) are substantially lower than those reported where certain Western ore is used.

(b) Separate Wastes—Gas wash wa-

TABLE IV.—Fluorides in Blast Furnace Gas Wash Water

Plant Designation	Fluorides (p.p.m.)	Fluorides per Ton of Pig Iron (lb.)
4	1.01	0.0331
5	1.27	0.0632
6	1.14	0.109
7	0.37	0.00807
8	0.75	0.0154

ter, as previously discussed, is the combination of waters from the washers and from the precipitators. With certain exceptions, these wastes are produced separately and need not necessarily be handled together. The exceptions occur when precipitators or stationary disintegrators are superimposed on wash towers, in which cases the two wastes are mixed. These wastes may be combined for removal of settleable material, but some mills treat only the water from the washer (Figure 1). The characteristics and volumes (Table V) of these separate waste waters are therefore of interest. These data show that the precipitator wastes make up about 17 per cent of the combined flow of the two wastes, but contain only 1.5 per cent of the suspended solids. The precipitator waste is of more importance than indicated by this comparison because it contains a significant portion of the extremely fine particles which are the most difficult to remove by sedimentation and the most likely to remain in the waste after treatment. Furthermore, intermittent flushing of the precipitator collecting electrodes, causing temporary increase in discharge, may cause sufficient hydraulic overload on sedimentation systems at those periods to interfere with normal efficiency.

(c) Comparison of Wastes from Various Type Washers—Considerable variation occurs in the volume of water used for gas washing per ton of product basis depending, among other factors, on the type of washer employed. Even among washers at the same plant and of the same construction, the use of wash water per ton of pig iron produced ranged from 2,250 to 4,300 gal. These washers utilized sprays and mechanical mixing with no contacting layers. The quantity of suspended solids removed by these washers was less variable, ranging from 34 to 50 lb. per ton of product. A fifth washer at the same plant contained layers of tile grids presenting extensive contacting surfaces; this washer used only 1,500 gal. of water per ton of pig iron produced. It removed comparable amounts of suspended solids (39 lb. per ton of pig iron produced). At another plant, towers with similar contacting layers used more than 3,900 gal. per ton of pig iron produced. Water consumption figures determined by

TABLE V.—Volume and Characteristics of Primary Gas Washer Discharge and of Precipitator Discharge

Plant No.	Flow, Per Ton of Pig Iron (gal.)	Total Susp. Sol.		Vol. Susp. Sol.		Iron, as Fe	
		(p.p.m.)	Per Ton of Pig Iron (lb.)	(p.p.m.)	Per Ton of Pig Iron (lb.)	(p.p.m.)	Per Ton of Pig Iron (lb.)
(a) Primary Gas Washer Discharge							
1	3,940	780	25.7	116	3.8	520	17
(b) Precipitator Discharge							
1	790	67	0.4	9	0.06	14	0.09

Public Health Service studies, and confirmed in the technical literature, for the various types of washing equipment are as follows:

Unit	Water Consumption Per Ton of Pig Iron (gal.)
Primary washing towers	800–4,300
Secondary washers:	
Disintegrators, rotary	1,100–1,700
Disintegrators, stationary	1,200–1,300
Electric precipitators	220–1,100

The dust content in the gas coming from any furnace varies considerably from time to time. Variations have a marked influence on the efficiency of gas cleaning equipment (6). When wedged stock falls inside the furnace, the explosion-like release of gas carries abnormal quantities of dust from the furnace.

Furnace Cooling Water

The walls of modern blast furnaces are cooled by means of water passing through enclosed metal conduits, known as cooling plates, which are laid in the brickwork of the wall. These coolers usually are employed only in the lower sections of the furnace where the temperatures are highest. At times, when refractory linings are worn away to the point where the outside of the furnace wall becomes excessively hot, external sprays of water on the furnace wall may be employed. Cooling water volumes vary from 4,000 to 8,500 gal. per ton of pig iron produced. No pollutional material is added to this cooling water. Temperature increases for the volume ordinarily employed are slight, ranging from 10° to 20° F. In some plants, where acid river water is used, the corrosive characteristics of the water are reduced by lime neutralization prior to its use for cooling.

Miscellaneous Wastes

One minor discharge originates from an emergency overflow in the side of the gas washer. This overflow is for the purpose of permitting water to escape in case the drain from the bottom of the washer becomes plugged. A continuous flow of water is provided to maintain the seal and thus prevent the escape of a large quantity of gas in case the water is blown out by excess gas pressure. This water amounts to about 25 g.p.m. per washer and passes through in an unpolluted condition.

Another miscellaneous waste is engine room floor washings and waste lubrication oils from blowing engines. At some plants burning coal as auxiliary fuel, ashes may be sluiced to the sewer.

Pollutional Effect

Suspended solids are recognized as the most objectionable constituent in blast furnace gas wash water. When efficient recovery of these solids is not accomplished, the heavier solids deposit in the immediate vicinity of the sewer outfall and require routine dredging. The lighter solids carry farther in the receiving waters, eventually settling out to the detriment of normal aquatic life. The suspended particles of ore and coke impart a deep gray to black appearance to the waste. This apparent color and turbidity in a stream may be objectionable from the standpoint of recreation and subsequent treatment.

The literature is replete with information pertaining to the pollutional effect of phenol and the objectionable taste it imparts to chlorinated drinking water. It should suffice to emphasize that some gas wash waters contain phenol in significant concentrations. Furthermore, it is known that a substantial amount of blast furnace coke is currently quenched with ammonia still waste. The phenol problem can be viewed in its proper perspective by considering that production of 10,000 tons of pig iron may give a waste containing a minimum of 250 lb. of phenol.

Cyanide in the gas wash water is low but consistently above concentrations lethal to fish. When mixed with the total discharge from an integrated steel

mill the cyanide concentrations are reduced. However, this cyanide could cause objectionable pollution when the gas wash water is discharged to a small stream.

The maximum desirable level of fluoride in drinking water is 1.5 p.p.m. Fluoride-bearing wastes causing this level to be exceeded in a stream could create a public health problem.

Calcium and magensium compounds in solution in the wastes increase the hardness of the receiving waters and thus may detract from their quality for subsequent uses.

Remedial Measures

The applicability and accomplishments of certain remedial measures have been established by their wide use; others are yet to be proven on plant scale. The measures include plain sedimentation, coagulation, dry cleaning, and operation at reduced gas velocities achieved by top pressure or use of oxygen.

Waste Treatment

(a) Plain Sedimentation—Treatment of wastes from blast furnace gas washing is limited almost entirely to plain sedimentation (7). Such treatment is practiced at most steel mills today. Material removed by sedimentation is composed to a large extent of iron ore and to a lesser degree of coke. Both materials are valuable. The fine ore can be fused to larger particles and recharged to the furnace. Combustion of the coke in the sintering process provides some of the heat required.

Sedimentation units employed are of both circular and rectangular design. Modern units are equipped with sludge collecting mechanisms. Some of the older settling basins are divided into two units and have no facilities for collecting and removing sludge. Such units must be cleaned routinely with a clam-shell dredge.

Data on suspended solids removal accomplished by plain sedimentation at three steel mills are given in Tables VI and VII. Each of these units was equipped for continuous sludge collection and removal. There was no attempt in these studies to compare different types of equipment, but rather to show what could be expected from plain sedimentation. However, comparison of suspended solids in the effluents, expressed on production basis, reveals superior efficiency of certain designs. A recent installation has been described by Walton (17).

Sludge removed from the sedimentation units is pumped or removed pneumatically to a filter for dewatering. The sludge contains from 45 to 65 per cent solids. The slurry withdrawn from the tank may be recirculated to obtain higher concentrations sufficient to facilitate filtration or a second settling period may be provided for the slurry in order to reduce its moisture content before filtration.

Filtration of the sludge is necessary to reduce the moisture content to that

TABLE VI.—Suspended Solids Recovery from Gas Wash Water by Plain Sedimentation

Plant No.	*Q/A* (g.p.d./sq. ft.)	Theor. Detention Period (min.)	Suspended Solids			
			Infl. (p.p.m.)	Effl. (p.p.m.)	Removal (%)	Effl., per Ton of Pig Iron (lb.)
1	735	120	670	64	90	2.5
2	1,710	49	2,010	380	81	9.4
3a	845	98	3,250	196	94	5.2
3b	890	82	4,360	205	95.5	4.4
3c	1,970	58	3,260	75	97.6	1.5

TABLE VII.—Iron and Volatile Suspended Solids Recovery from Gas Wash Water by Plain Sedimentation

Plant No.	Theor. Detention Period (min.)	Iron, as Fe				Vol. Suspended Solids (Coke)			
		Infl. (p.p.m.)	Effl. (p.p.m.)	Recovered		Infl. (p.p.m.)	Effl. (p.p.m.)	Recovered	
				(p.p.m.)	Per Ton of Pig Iron (lb.)			(p.p.m.)	Per Ton of Pig Iron (lb.)
1	120	397	45	352	13.8	101	12	89	3.5
2	49	676	161	515	12.1	180	54	126	3.0

suitable for sintering. Two types of filters are in general use—the cylindrical or drum type, and the disc type. The filtrate should be returned to the sedimentation tank influent to avoid solids losses during abnormal filter operations. The filter cake, containing 18 to 22 per cent moisture, is transported to the sintering plant.

The composition of the sludge varies with the size of particle. Large particles contain a minimum of about 35 per cent iron; the small particles contain less than 10 per cent. Sludge solids averaged from 32 to 66 per cent iron (5). The dust contains between 5 and 15 per cent carbon, which has significant heating value. It has been estimated that flue dust containing 15 per cent carbonaceous matter has sufficient fuel value to sinter more than three times its own weight of additional fine ore.

Sintering was originally undertaken to dispose of dust, but today it is used extensively to agglomerate fine ore. The annual capacity of sintering plants in the United States in 1948 was 18,000,000 gross tons. The flue dust, filter cake, fine ores, and mill scale are mixed with suitable amounts of fine coke and placed in a dampened condition on a traveling grate. The coke is ignited by gas; then as it moves along the grate is burned by a strong downdraft of air. Incipient fusion agglomerates the fine material into particles of such size and strength that they may be satisfactorily charged to the blast furnace.

Scale deposits have proven a problem in long sludge lines. These deposits can be removed by pumping a solution of murjatic acid through the lines. Routine flushing of the sludge lines with water has been reported effective in minimizing scale formation.

(b) Coagulation—Practically all suspended material can be removed by coagulation and sedimentation. One plant, which practices recirculation of the gas wash water, treats the waste by coagulation and sedimentation after it has passed through the system several times. Alum is used as the coagulant. The use of ferric and ferrous sulfate as coagulants for this purpose has been suggested (8). Sufficient alkalinity is present from the alkali content of the dust to react with the ferrous or ferric compounds to produce a floc. An abundance of ferrous sulfate is available at all steel mills employing sulfuric acid pickling. Most blast furnaces are part of integrated steel plants having such pickling operations in the rolling mill division. Coagulation gives a highly clarified treated waste, recovers additional iron and carbon, and utilizes waste pickle liquor. Increased sludge volume and difficulty in dewatering of the sludge are deterring factors (18).

(c) Segregation and Re-Use—Segregation of blast furnace gas wash water and its recirculation in a separate system has been reported at one plant.

Treatment of the water consists of plain sedimentation with intermittent use of coagulants. Some of the water is withdrawn for cooling slag by direct sprinkling. Such a system eliminates the release of water to waste and reduces water demand. In addition, loss of materials is eliminated (9). If maintenance of sufficiently low temperature becomes a problem, discharge of the coagulated and settled water should not be objectionable. Likewise, excess water due to increases in volume from condensation of vapor in the gas might be so treated before discharge.

One of the washers illustrated in Figure 2 employs recirculation. A small settling unit removes readily settleable material from the wash water at the washer and the supernatant is recirculated to the sprays in the washer. Fresh water use in this washer is 20 gal. per 1,000 cu. ft. of gas; about 40 gal. are recirculated.

Elimination

(a) Dry Filtration—Dry cleaning of blast furnace gas in all stages eliminates wash water use and is therefore the most effective remedial measure. Dry cleaning is accomplished by following the usual dry dust equipment with apparatus for filtering the gas through fine meshed fabric bags. Efficiency of the bag as a filter is increased as a dust mat forms with service, giving results comparable to electric precipitators. The dust is removed by taking units of the filter out of operation, shaking, and counterblowing them. The first units of this type used cotton bags, which necessitated lowering of the gas temperature to prevent charring of the bags. The gas also had to be maintained at temperatures above its dew point. Even with these serious complications, 13 foreign plants were reported using the system (2).

A recent development, tested on pilot-plant scale, employs filters made of asbestos and glass fiber and a new design for mounting the bags (4). This development eliminates the necessity for cooling the gas and minimizes wear and tear on bags. The advantages claimed for this filter development as compared to gas washing installations are impressive. Among the advantages are: (a) elimination of water pollution, (b) lower installation and operation costs, (c) less space required, (d) cleaner gas, (e) higher flame temperatures and improved heat recovery, and (f) less pressure loss. Recovering the dust in a dry state makes possible injection of the dust into the blast furnace at the mantle by means of compressed blast furnace gas. This practice has been followed successfully in Europe since 1926. The necessity of settling the dust from wash water, and the filtering and sintering operations are eliminated. The cost of flue dust disposal is reported to be considerably reduced.

(b) Reduction Measures.—Short of complete dry cleaning of the gas, it is obvious that the greater the proportion of the dust removed in the dry state the less will remain for wet washing operations. Optimum design of momentum and cyclone dustcatchers is discussed by Jennings (2) and by Kling (4). Contrary to what might be expected, the different phases of dust cleaning do not each in turn remove particles down to a certain size. A substantial amount of even the finest particles is removed in the dustcatcher and primary wash phases (2).

Sintering of ores lessens dust production by, in effect, removing the dust before it is charged to the furnace. The fine ore particles are combined by incipient fusion into larger particles. Liberal use of water on stock charged to the furnace is stated to reduce flue dust production.

Electric precipitators may be operated dry, thus eliminating the waste irrigation and spray water. However, the dry type is reported not as efficient as the wet type.

Cleaning of blast furnace gas beyond the dry dustcatcher phase is for some uses, such as for under-firing boilers,

TABLE VIII.—Flue Dust Related to Top Pressure and Air Blast

Plant No.	Top Pressure (p.s.i.)	Air Blast (c.f.m.)	Flue Dust, Per Ton of Product (lb.)
1	2	78,000	270
	3.1	72,200	213
	9.7	73,400	145
	9.7	83,000	170
2	Normal	67,500	280
	10	80,000	240
3	Normal	85,000	278–305
	10	95,600	125

unnecessary or even undesirable according to Gilg (10). It follows that wet washing of a portion of the gas could be omitted; however, as previously stated, this practice will contribute to air pollution.

As explained in the section on process, reduced velocities of gas in the blast furnace are achieved under certain conditions of top pressure operation (11)(12)(13). Top pressure experience is rather limited, but top pressure operation at reduced velocities has decreased considerably the quantities of flue dust, as shown in Table VIII.

This accomplishment in reduction of flue dust is also apparent from the data on volume and character of wastes reported in a previous section. Suspended solids in gas wash water wastes of a furnace operating at about 10 p.s.i. top pressure averaged 46 lb. per ton of pig iron produced, whereas those of a furnace at the same plant operating under normal pressure amounted to 63 lb.

In top pressure operation, increased pressure advantages are not limited to the blast furnace itself, although of the 17 furnaces in the country reported using high pressure, many limited pressure to the furnace only. Operation of gas cleaning equipment under pressure reduces gas velocities in the equipment, increasing the efficiency of the gas cleaning units.

The use of oxygen-enriched air for the furnace blast has received attention in recent years. Two companies have reported use of oxygen-enriched air blast. Such practice should reduce the quantity of flue dust because of reduced gas velocities through the furnace.

Summary

Suspended solids from blast furnace gas wash water, when dewatered and sintered, comprise valuable material which is suitable as a portion of the blast furnace charge. Phenol, cyanide, and fluoride, although normally present in the gas wash water in relatively low concentrations, may create objectionable pollution in some receiving waters.

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EFFECT OF SYNDETS ON THE ACTIVATED SLUDGE PROCESS

In an effort to detect and trace the synthetic detergents believed by some to be responsible for various operational problems in sewage treatment plants, a fundamental study of their effect on the activated sludge process has resulted in development of a new method for the determination of anion-active syndets. Under the sponsorship of the National Institutes of Health, USPHS, the study is being conducted at New York University by Gail P. Edwards and Martin E. Ginn.

The new method is a two-phase titration procedure which depends on the titration of an anion-active detergent with the cation-active detergent, cetyltrimethylammonium bromide, in the presence of hexane. A dyestuff, such as bromphenol blue or azo phloxine, is dissolved in the water layer and the end point is indicated by the formation of a cation-active detergent salt of the dye which moves into the hexane layer and colors it. Interference by soaps and proteins has been eliminated by pH adjustment to 7.5, and low results caused by calcium and magnesium compounds have been avoided by the use of versene.

Preliminary laboratory experiments have been started to study the relation of surface tension and oxidation-reduction potential to frothing by anionic detergents.

PAPER PULP WASTES TREATMENT—ORANGEBURG MANUFACTURING CO.*

By William E. Stanley and Robert D. Ellis

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Complying with stream standards of the New York Pollution Control Board for Sparkill Creek, the Orangeburg Manufacturing Co., Inc., has installed liquid wastes treatment works, in operation since early in July 1953, at its factory in Orangeburg, N. Y.

The liquid wastes treatment works were planned and basic design factors were set up after an extended study of the liquid wastes beginning in 1949. The treatment works were then constructed as an integral part of an expansion of the company's pipe manufacturing facilities. Included in the factory expansion were substantial relocation of liquid wastes outlets and some improvements in operation which made feasible a reduction in waste quantities per unit of product, but enlarged mill capacity has resulted in an increase in total liquid waste flows.

Orangeburg sewer pipe and Orangeburg electrical conduit have been manufactured at the present factory location since 1893. The product is a hard coal-tar pitch compound reinforced with a preformed wood fiber structure, about 75 per cent hard coal-tar pitch and 25 per cent wood fiber. The raw materials include coal-tar pitch, selected clean waste paper, and mineral fiber.

Surface water and liquid factory wastes drain naturally south into a small, well-defined channel known as Orangeburg Creek (Figure 1). This channel runs easterly about 3,300 ft. across swampy land to a juncture with Sparkill Creek. The drainage basin of Sparkill Creek below Orangeburg Creek has been rapidly becoming urbanized in recent years. The proposed Palisades Inter-State Parkway passing through the basin will lead to greater urbanization.

Sources of Liquid Wastes

Two general types of liquid wastes were found—one containing paper pulp and de-inking material, the other containing miscellaneous nonfibrous wastes. The major source of liquid wastes is the pulping and washing of waste paper and is largely produced in the "beater" room. A small quantity of liquid wastes containing pulp fiber comes from accidental chest overflows and from storage chest washout at times of periodic clean-ups.

Miscellaneous nonfibrous wastes included relatively minor quantities; about 3,600 g.p.d. of power plant ash washings, 900 g.p.d. of water softening blowdown, 8,640 g.p.d. of continuous boiler blowdown drainage, 14,400 g.p.d. of continuous spray wash for pipe trimmings, and about 500 g.p.d. of oil emulsion losses, or a total of about 28,000 g.p.d.

Liquid Waste Quantities and Characteristics

Waste-water flows were gaged during 1949, by a temporary V-notch weir. Illustrative flow rates are summarized in Table I.

Limited laboratory analyses of composite samples during the temporary gagings prior to design gave solids

* Presented at 26th Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Jan. 21–22, 1954.

components of the liquid wastes as recorded in Table II.

Two composite samples analyzed by State Department of Health laboratories gave B.O.D. values as recorded in Table III.

These data (Tables II and III) indicated that sludge-producing components of the waste waters were more important with reference to stream pollution than were the oxygen demand components. Tests of solids in liquid wastes during 4-hr. week-end clean-up periods showed the quantity of solids discharged ranged from 947 to 3,823 lb. (dry weight), large portions of which were gritty materials that had settled in pulp storage chests. New stock preparation facilities (beater room) and passage of the pulp stock through improved treatment has resulted in less grit in the liquid wastes.

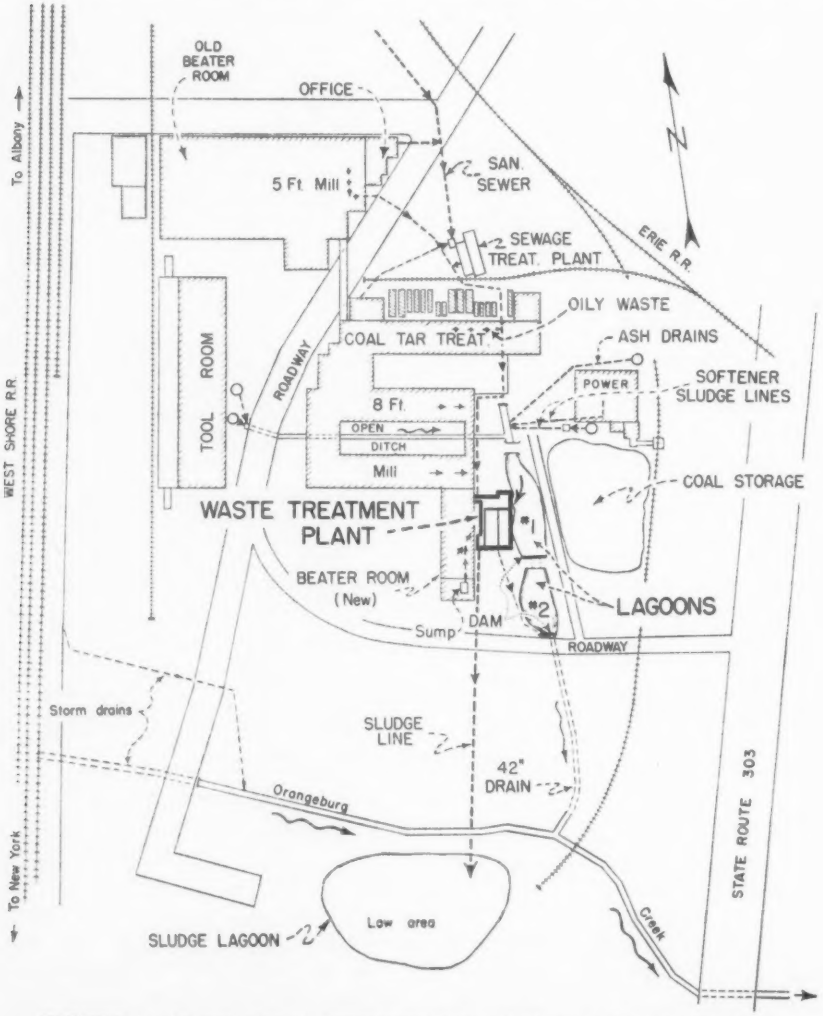

FIGURE 1.—General plan of Orangeburg factory drainage and treatment plants.

TABLE I.—Liquid Wastes Flow Rates, 1949 Gagings

Date (1949)	Total Flow[1] (g.p.d.)	Flow Rate (g.p.m.)		Ratio, Peak to Average
		Daily Av.	Peak	
Oct. 6–7	322,000	224	365	1.63
Oct. 17–18	338,000	235	440	1.87
Nov. 4–5	327,000	228	482	2.12
Dec. 12–13	373,000	259	472	1.83
Repr.[2]	350,000	250	500	2.0

[1] By weir.
[2] Selected as representative.

Laboratory analyses of a sample of the liquid waste entering the treatment works (January 7, 1954) show a lower B.O.D. concentration, but the solids concentrations were about the same as in 1949 (see Table IX).

Pilot-Plant Experiments

Of the several methods of treatment considered, the following were given special attention.

Chemical Coagulation and Sedimentation

Laboratory bottle tests indicated that good clarification could be obtained with chemical coagulation and sedimentation. Also, observations of operation of liquid wastes treatment plants with similar wastes characteristics—notably the treatment plant of the Beach and Arthur Paper Company at Modena, Pa.—gave assurance that chemical precipitation would result in a well-clarified effluent.

Solids-Contact Process

Operation results were observed at several waste treatment plants using the relatively new solids-contact process for clarification. There were two major objections, however; the process had not been well tried out as yet, and large quantities of chemicals were required with no opportunity to operate without the use of chemicals during seasons when stream flows might not require a highly clarified effluent.

Flotation Processes

Several flotation processes were studied. A series of pilot-plant experiments was made during October and November 1950 using the Bird-Gibbs flotation process. A pilot test unit and the services of an experienced operator were engaged. Several series of short operating tests were run. Problems of attending the pilot unit and interference with operation by materials

TABLE II.—Solids in Orangeburg Liquid Wastes, 1949 Analyses

Date (1949)	Aver. Flow (g.p.m.)	Total Solids		Suspended Solids		
		(p.p.m.)	(lb./day)	(p.p.m.)	(lb./day)	Vol. (%)
Oct. 6–7	224	1,030	2,750	620	1,670	47
Oct. 17–18	235	1,270	3,560	776	2,190	45
		1,278[1]	3,600	710[1]	2,000	45[1]
Nov. 4–5	228	1,260	3,447	584	2,185	41
Dec. 12–13	259	960	2,990	548	1,710	42
		940[1]	2,930	490[1]	1,520	37[1]
Repr.[2]		1,100	3,200[3]	650	1,900[4]	43

[1] Analyses by Lab. Division, State Dept. of Health.
[2] Selected as representative.
[3] Vol. matter, 45 per cent.
[4] Resulting population equivalent (at 0.19 lb. per capita per day) = 10,000.

TABLE III.—B.O.D. in Liquid Wastes, 1949 Analyses

Date (1949)	Flow (g.p.m.)	5-Day B.O.D.	
		(p.p.m.)	(lb/day)
Oct. 17–18	235	147	415
Dec. 12–13	259	120	373
Average	247	133	394[1]

[1] Resulting population equivalent (at 0.17 lb. per capita per day) = 2,300.

too heavy to be floated, were the major influences controlling the length of test runs. Also, trouble was experienced with the temporary pumping unit used to lift waste water from Orangeburg Creek. During a 24-hr. test on November 1, 1950, a composite sample was collected and sent to the State Department of Health laboratories. A portion of the sample also was analyzed in the Orangeburg laboratory. Analytical results are recorded in Table IV.

Flow rates through the pilot unit averaged 72 g.p.m., equivalent to a loading rate of 2.5 g.p.m. per sq. ft. of water surface. The total flow for the 24-hr. test was about 104,000 gal. Chemicals required to maintain an optimum pH of 10.5 to 11.0 were 7 grains per gallon of alum and 22 grains per gallon of lime. Short test runs were made at 85 g.p.m. (3 g.p.m. per sq. ft.), 90 g.p.m., and 100 g.p.m. to determine the probable effect of higher flow rates. These tests indicated that 3 g.p.m. per sq. ft. may have been the upper application rate limit for the pilot unit used.

The flotation process was considered unsatisfactory for the Orangeburg wastes, partly because of the need for sedimentation to remove heavier solids, and partly because of the considerable and continuous amounts of chemicals required.

Filtration Through Pipe Cuttings

Over the years large quantities of black pipe cuttings (from tooling of Orangeburg pipe ends) have been dumped in a fill adjacent to the factory. These solid wastes, together with fragments of broken pipe, wooden boxes, large quantities of ashes from the power plant, and other solid debris, have formed a large (several acres) relatively porous fill. Small laboratory tests and short-time experiments indicated that mechanical filtration through this fill would clarify the liquid wastes.

Accordingly, a pumping station was installed and full-scale experimental tests were made to clarify the liquid wastes by filtration through dry solid wastes. Starting November 11, 1951, wastes partially settled through a lagoon were discharged onto 7,500 sq. ft. of prepared filter area at rates of 265 to 271 g.p.m. for about 7 days for each of two area divisions. After the flow filtered away, the beds were renewed by scarifying the surface with the bulldozer used on the dump. Then additional quantities could be applied. The filters were operated sporadically through the next several months, with frequent down periods due to mechanical pump troubles, until May 27, 1952.

Early (1949) laboratory tests gave results as recorded in Table V.

Visual observations showed a relatively clear effluent seeping out at the bottom of the solid wastes dump. Grab samples analyzed for solids gave results as recorded in Table VI. It was concluded that the pipe cuttings fill could be used reasonably satisfactorily for good clarification of settled liquid wastes, but the labor and bulldozer time

TABLE IV.—Results of Flotation Process Pilot-Plant Experiment, 1950

Determination	Laboratory	Results (p.p.m.)		Red. (%)
		Infl.	Eff.	
Solids, total	State	1,218	571	53
	Obg.	1,060	630	—
Solids, susp.	State	776	86.5	89
	Obg.	692	86	88
B.O.D., 5-day	State	122	51.6	58

TABLE V.—Results of Experimental Filtration Through Pipe Cuttings[1]

Determination	Oct. 17–18, 1949		Dec. 12–13, 1949	
	Unfilt.	Filt. Effl.	Unfilt.	Filt. Effl.
pH	7.7	7.7	7.3	7.3
B.O.D., 5-day (p.p.m.)	147	114	120	96
Reduction (%)	—	22	—	20
Chlorides (p.p.m.)	18	22	16	5
Alkalinity (p.p.m.)	167	168	134	132
Total solids (p.p.m.)	1,278	631	940	578
Volatile (p.p.m.)	555	238	330	194
Volatile (%)	44	38	35	34
Fixed (p.p.m.)	723	393	610	384
Diss. solids (p.p.m.)	568	502	450	448
Volatile (p.p.m.)	240	202	148	169
Volatile (%)	42	40	33	38
Fixed (p.p.m.)	328	300	302	279
Susp. solids (p.p.m.)	710	129	490	130
Volatile (p.p.m.)	315	36	182	25
Volatile (%)	45	28	37	19
Fixed (p.p.m.)	395	93	308	105
Reduction (%)	—	82	—	73

[1] Analyses by Division of Laboratories, New York State Dept. of Health.

involved and the problem of operating during inclement weather conditions would be unsatisfactory as compared to a central liquid wastes treatment plant.

Sludge Disposal Studies

The dry wastes dump with large daily additions appeared to furnish an excellent place for sludge disposal by admixture of partially dewatered sludge solids with the dry wastes. Also, experience with sludge residues in the filtration experiments indicated that the liquid sludge would dewater rapidly and would not decompose rapidly enough to produce objectionable odors. Apparently the coal-tar compounds in the sludge retard decomposition.

TABLE VI.—Illustrative Results of Large-Scale Filtration Experiments, 1951

Item	Susp. Solids (p.p.m.)	Ash in Susp. Sol. Sample (%)	pH
Raw wastes	625	48	7.8
Pump discharge	145[1]	70	7.4
Filter effl.	38[2]	66	7.4

[1] After partial settling in lagoon.
[2] Collected at foot of solids wastes dump; suspend solids removal, 94 per cent.

An experimental sludge filter on 12-sq. ft. area was constructed with a bottom coarse stone layer plus 4 in. of finer stone and a top 12-in. layer of pipe cuttings. A 6-in. layer of sludge was placed on the prepared drying bed. Water began to trickle out the bottom within 5 min. The sludge volume was reduced about 40 per cent in 4 hr., about 50 per cent in 12 hr., large shrinkage cracks appeared after 3 days, and the sludge was quite dry after 14 days.

These observations of fast drying, together with the experience of sludge residues in the filtration tests and an absence of objectionable odors, led to the decision to dispose of liquid sludge from the initial wastes treatment installation by placing it on the dry wastes dump, allowing time for partial dewatering, and then mixing it with the daily disposal of dry wastes. An additional 23 acres of low swampy area had been acquired for extension of the dry wastes dump.

Selection of Treatment Process

The assigned classifications (May 1, 1953) of the New York State Water Pollution Control Board included Class F for Orangeburg Creek and Class D for Sparkill Creek for a considerable distance below Orangeburg Creek.

Early gagings and laboratory analytical data, together with downstream observations along Orangeburg and Sparkill Creeks, indicated that removal of suspended solids would be the most important requirement and that provision for adequate suspended solids removal should provide the necessary degree of treatment to maintain the specified stream quality standards, excepting during periods of extreme low-water flows.

The solids-contact clarification process and the flotation process were considered undesirable largely because these two processes would require continuous quantities of chemicals with no possibility of omitting chemical treatment at times of high stream flows. Also, the lighter solids might cause difficulty by floating in the solids-contact process, whereas the pilot-plant experiments plainly indicated need for preliminary sedimentation to remove certain heavier items ahead of flotation. Filtration through the dry solid wastes dump was discarded for reasons already explained.

Accordingly, the liquid wastes treatment plant as selected, designed, constructed, and presently in operation comprises mechanical flocculation and sedimentation as normal treatment processes, with provision for adding coagulants ahead of the flocculator during periods of low stream flows when more complete removal of solids may be desirable.

Treatment Plant Elements

The main elements of the liquid wastes treatment plant, as constructed, comprise the following:

1. Pipes into inlet sump:
   (a) Cloudy filtrate from beater room filters.
   (b) Drainage from the 8-ft. mill.
   (c) Excess white water from the beater room sump.
   (d) Oily waste from the coal-tar treating plant.
   (d) Pump station discharge of waste waters reaching lagoon No. 1.

2. Chemical building, including two dry feeders, a mixing chamber, and a propeller-type rapid mixer.

3. Focculation chamber with paddle-wheel agitating equipment.

4. Two rectangular sedimentation tanks with chain-type collectors.

5. Measuring weir and integrating recorder at sedimentation tank outlets to control the chemical feeders.

6. Outlet sewer to Orangeburg Creek.

7. Pumping station with two non-clog liquid wastes pumps and two plunger-type sludge pumps.

8. Two lagoons to catch any overflows or spills from any part of the factory. Lagoon No. 1 drains into the wastes pumping station.

These several plant elements are shown in Figures 2 and 3.

Basic Design Factors

The treatment works were designed on the basis of handling white water and de-inking solids from newsprint pulp at an average flow rate of 500 g.p.m. (720,000 g.p.d.), and maximum and minimum flow rates of 700 g.p.m. (908,000 g.p.d.) and 200 g.p.m. (290,000 g.p.d.), respectively. The average concentration of suspended solids was assumed at 650 p.p.m. The dry weight of suspended solids in the raw wastes was calculated as 3,900 lb. per 24 hr., with a 24-hr. maximum of 5,500 lb. and a peak (during periodic factory clean-up) of 4,000 lb. per 4 hr.

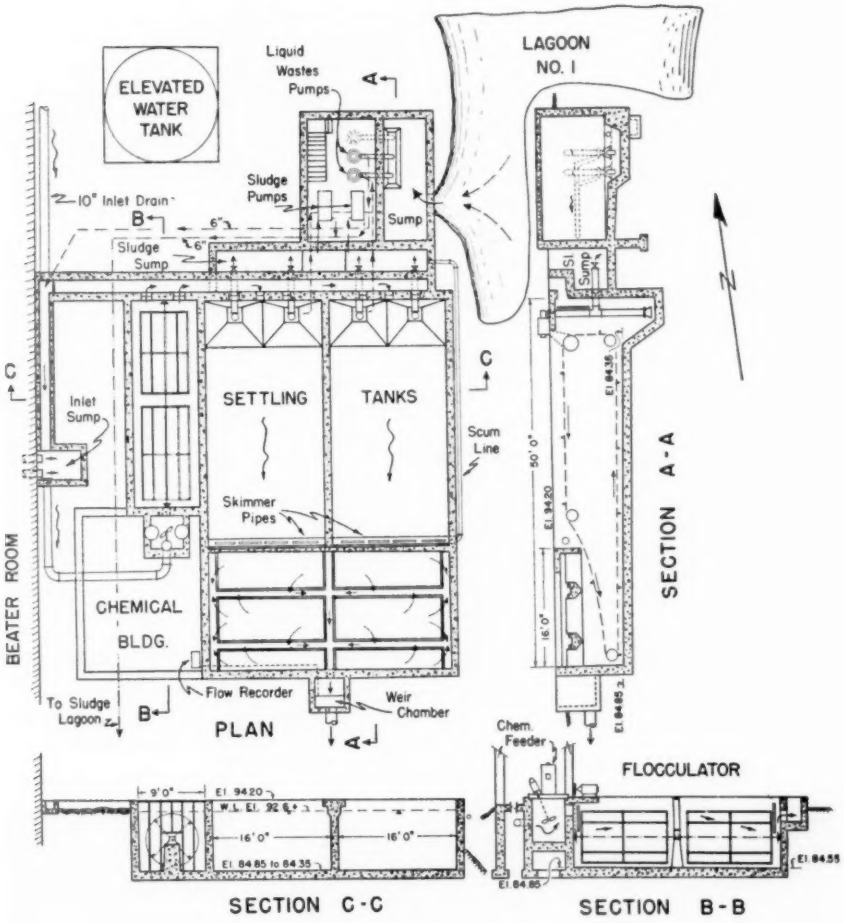

FIGURE 2.—Treatment plant layout and sections.

TABLE VII.—Design Overflow Rates and Velocities in Flocculation Basin and Settling Tanks

Unit	Flow (g.p.m.)	Overflow, per Sq. Ft.		Vert. Vel. (ft./hr.)	Long. Vel. (ft./min.)	Weir Overflow, per Lineal Foot	
		(g.p.m.)	(g.p.d.)			(g.p.m.)	(g.p.d.)
Flocculator[1]	700	2.8	4,000	22.2[3]	1.3[3]	—	—
Set. Tanks[2]	500	0.31	450	2.5[4]	0.26[4]	3.2	4,600[4]
	700	0.44	630	3.5[3]	0.37[3]	4.5	6,400[3]

[1] 252 sq. ft. of surface area, 28 lin. ft. of travel.
[2] 1,600 sq. ft. of surface area, 50 lin. ft. of travel, and 157 lin. ft. of weir.
[3] Maximum.
[4] Average.

Detention Periods, Overflow Rates, and Velocities

At a flow rate of 700 g.p.m. the flash mixer (4.5 ft. by 4.5 ft. by 4.6 ft. deep) has a nominal detention period of 1.0 min. Similarly, at 500 g.p.m. the flocculation chamber (9 ft. by 28 ft. by 8 ft. deep) and the settling tanks (two, each 16 ft. by 50 ft. by 8 ft. deep) have detention periods of 30 min. and 3.2 hr., respectively.

Surface and weir overflow rates, and vertical and longitudinal velocities, were provided as given in Table VII.

Plant Arrangement

The treatment plant, located near the southeast section of the beater room (Figure 1), has been arranged to take up a minimum of space and still leave room for possible future expansion to the east or to the south.

The liquid wastes are initially discharged into an inlet sump about 4 ft. by 6 ft. in plan and about 4 ft. deep, then through a 10-in. pipe into a rapid mixing chamber, thence into the flocculation chamber. Chemicals may be added by dry feeders placed directly above the rapid mixing chamber. The outflow from the flocculator enters the two settling tanks, flow rates being measured over a 60° V-notch weir at the outlet of the settling tanks. These plant units are shown in Figures 2 and 3. Nominal volumes of the three main plant elements are as follows:

Mixing chamber	700 gal.
Flocculation chamber	15,000 gal.
Settling tanks (2)	96,000 gal.

The inlet channel to the settling tanks was constructed with a uniform cross-section because of construction problems with steel forms. The channel is 18 in. wide, with 4-in. by 6-in. corner fillets, and designed to flow about 10 in. deep.

The outlet 16 ft. of the settling tanks are provided with two cross-collectors and three longitudinal effluent collectors providing 157 lin. ft. of effluent weir, thus maintaining a maximum computed weir overflow rate at 6,400 g.p.d. per lineal foot.

The effluent passes through about 145 ft. of 18-in. corrugated steel pipe sewer and is discharged into a 42-in. main drain below the dam for lagoon No. 2 (Figure 1).

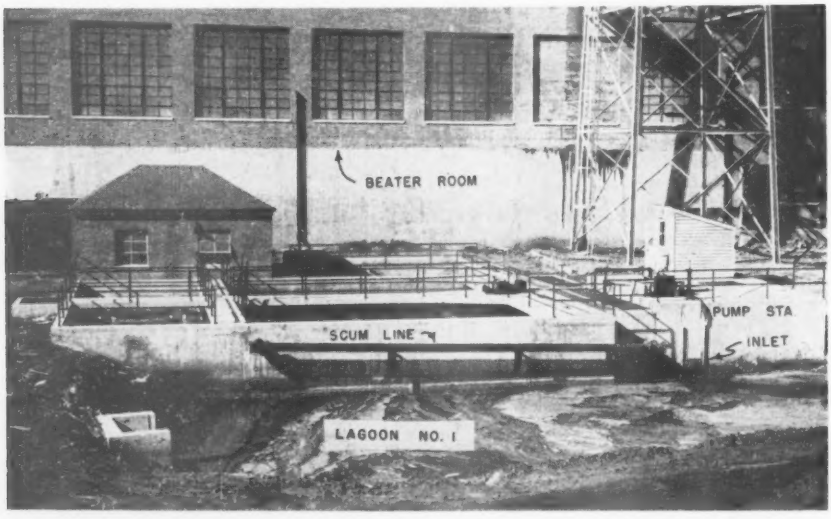

FIGURE 3.—Liquid wastes treatment plant at Orangeburg Manufacturing Co.

Pumping Station

Two non-clog centrifugal liquid wastes pumps and two plunger-type sludge pumps are located in the pumping station at the north end of the sedimentation tanks (Figures 2 and 3). The pumping station, comprising a wet well and a dry well for the pumping equipment, functions to receive such liquid wastes as may flow into lagoon No. 1 and discharge them into the channel leading to the inlet chamber, thence through the flocculator to the settling tanks. It was anticipated that the flow rates of liquid wastes reaching lagoon No. 1 would be reduced progressively. There are several small flows which would be quite difficult to collect into the treatment plant by gravity. Also, potential spills or overflows of storage tanks would enter lagoon No. 1 and be pumped into the treatment plant.

The elevated water storage tank (Figure No. 3) alongside the pumping station is potentially a source of partial flooding of the pumping station dry well. Accordingly, the motors on the four main pumping units were raised as high as they reasonably could be.

Function of Lagoons

Two lagoons were constructed by excavating and widening the drainage ditch and constructing two barriers across the ditch with adjustable stop-log overflow sections. Lagoon No. 1 catches any waste waters which may spill over or not reach the collector piping and drains directly into the wet well of the pumping station (Figure 3).

Both lagoons would be storage sedimentation reservoirs in case of any failure of the liquid wastes treatment works or in case of any unusual spill of liquid wastes. It is expected that these two lagoons would prevent any spill of liquid wastes into Orangeburg Creek, hence into Sparkill Creek.

Sludge Disposal

The experience with dewatering of sludge led to the installation of sludge pumps and a pipeline to the pipe trimmings filters, where the sludge was discharged from July to about October 15, 1953. Use of the two beds was alternated about every two weeks. Time was too short for complete dewatering, but the sludge did dewater sufficiently to handle. At one time the sludge was almost completely dry and it was extremely difficult to handle because the sludge cake was just a big piece of fiberboard about 12 to 14 in. thick and 40 ft. wide by 80 to 90 ft. long.

The area was needed for pipe storage yards, so the sludge pipe was extended across Orangeburg Creek and sludge disposal now is by lagooning in a low area (Figure 1), which will probably last until late spring or early summer 1954, after which another lagoon may be constructed in another low area.

Operation

Routine supervision of operation of the liquid wastes treatment plant is under the factory maintenance department. The Shop Foreman is directly responsible for the plant, under direc-

TABLE VIII.—Average and Maximum Liquid Wastes Flow Rates, 1953 Operation

Month (1953)	Flow Rate[1]		Max. Rates (g.p.m.)	
	(g.p.d.)	(g.p.m.)	Daily	Peak[2]
Aug.	375,000	261	325	700
Sept.	392,000	272	328	720
Oct.	448,000	311	425	660[3]
Nov.	460,000	320	390	560
Dec.	525,000	365	450	700

[1] Per working day—24 to 26 days per month.
[2] Flow rates which occur several times per day.
[3] October 1–20; outlets from flocculator restricted on October 21 to even out surges into settling tanks; peak flow rate Oct. 22–31, 550 g p.m.

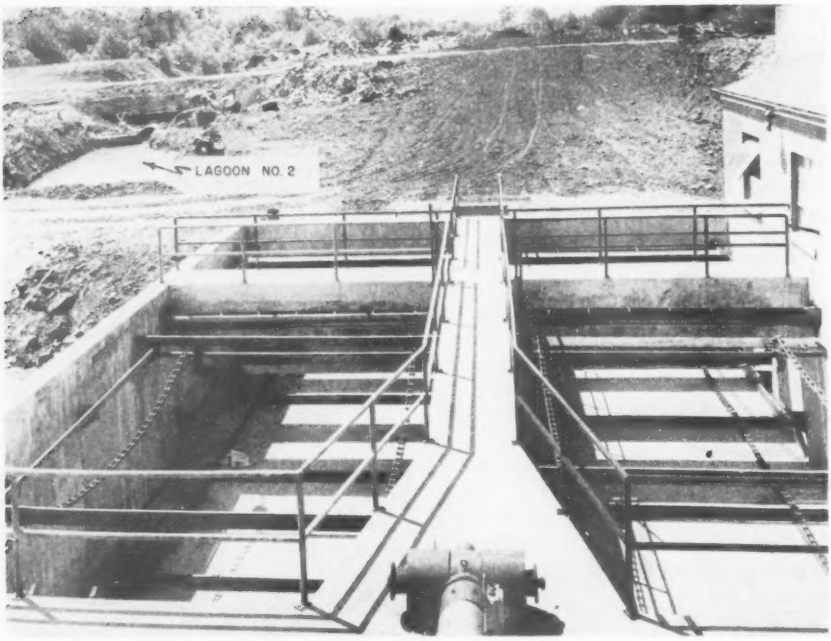

FIGURE 4.—View across sedimentation tanks to lagoon No. 2 and solid wastes dump, behind which is low area occupied by sludge lagoon.

tion of the Plant Maintenance Superintendent. Regular supervision on the day shift is by a Class A pipe fitter and his helper. The sludge hoppers are dumped at 8:00 AM, 1:00 PM, and 3:45 PM. On this shift about 2½ man-hours per day are required.

During the afternoon and night shifts, supervision is by a millwright and his helper. Sludge hoppers are dumped about 10:30 PM and 4:00 AM. About 1¾ man-hours are required on each of these shifts.

Routine supervision requires about 6 man-hours daily, partly due to the regular shop practice of always having a helper accompany the skilled pipe fitter (during the day) and the skilled millwrights (at night).

Additional attention of other maintenance men is required from time to time for different operating problems; for example, the bulldozer operator devotes some time to building and maintaining a special dike around the sludge lagoon. It is not feasible, however, to segregate the incidental time of the various maintenance men.

Flow Measurements

The monthly average and maximum flow rates from July to December, 1953, are given in table VIII.

Extreme momentary peaks may result from coincident discharge of the two wastes pumps and the two beater room sump pumps into the treatment works, but this rarely happens and then only for very short duration.

Extreme flow rates are possible as follows:

Wastes pumps, 2 @ 350–400 g.p.m. =	700– 800 g.p.m.
Sump pumps, 2 @ 200–225 g.p.m. =	400– 450 g.p.m.
Flow in 10-in. pipe from 8-ft. mill	300 g.p.m.
Filtrate from beater room filter	100 g.p.m.
Total	1,500–1,650 g.p.m.

The highest recording chart reading is 1,500 g.p.m., which flow rate has been reached only one time to date.

Use of Chemicals

The planning of the liquid wastes treatment anticipated the use of chemical treatment during periods of low flows in the Orangeburg and Sparkill Creeks. Alum coagulant and hydrated lime as a pH agent have been used to date. The use of alum was started September 14 and lime use was started October 5, 1953. The routine use of chemicals was discontinued November 24, 1953.

Chemical quantities used during 1953 were as follows:

Week Ending (1953)	Chemicals Used (lb.)	
	Alum	Lime
Sept. 18	350	—
Sept. 25	350	—
Oct. 2	50	—
Oct. 9	400	150
Oct. 16	400	—
Oct. 23	600	300
Oct. 30	400	150
Nov. 6	500	350
Nov. 13	500	350
Nov. 20	—	200
Nov. 27	—	50
Total	3,550	1,550

Chemicals were used on January 5, 6, and 7, 1954, when special samplings of raw and treated wastes were made for analytical tests by the State Department of Health. During the 12-hr. period when samples were being collected, 62 lb. of alum and 80 lb. of lime were used. The average flow during this period was 393 g.p.m. Analytical results of these tests are given in Table IX.

TABLE IX.—Operating Results[1] with Chemicals[2]—1954

Determination	Raw Waste	Plant Effl.	Rem. (%)
Turbidity (p.p.m.)	900	35	96
pH	7.3	7.2	
B.O.D., 5-day (p.p.m.)	114.0	68.0	40
Chlorides	15.0	15.0	
Alkalinity	177.0	170.0	
Grease	25.7	10.3	60
Total solids	1,129.0	460.0	59
Volatile	453.0	180.0	
Fixed	676.0	280.0	
Susp. solids	752.0	49.0	93
Volatile	268.0	24.0	
Fixed	484.0	25.0	
Diss. solids	377.0	411.0	—[3]
Volatile	185.0	156.0	
Fixed	192.0	255.0	
Non-settl. sol.	617.0	455.0	26
Volatile	216.0	176.0	
Fixed	401.0	279.0	
Settl. solids	512.0	5.0	99
Volatile	237.0	4.0	
Fixed	275.0	1.0	
Ml. per l., ½ hr.	64.0	0.0	100
Ml. per l., 1 hr.	51.0	0.0	
Ml. per l., 2 hr.	44.0	trace	

[1] 12-hr. composite samples collected Jan. 7, 1954, and analyzed by New York State Dept. of Health.

[2] Treated with 62 lb. of alum and 80 lb. of lime during 12-hr. sampling period.

[3] 34 p.p.m. increase.

DISPOSAL OF ELECTROPLATING WASTES BY ONEIDA, LTD.*

III. Plant Design

By Charles A. Walker, Barnett F. Dodge, and John Madden †

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A number of possible choices of equipment types and arrangements, any one of which would have provided for carrying out the treatments described in Part II,‡ were considered from the viewpoints of capital costs, operating costs, ultimate capacity for treating wastes, and freedom from the possibility of accidental contamination of the creek. The main methods considered were those originating in the possibility of operating 8, 16, or 24 hr. per day, and of operating on either a batchwise or a continuous basis. The scheme chosen involves batchwise treatment of silver-bearing wastes with sodium hypochlorite, and batchwise treatment of the alkali wastes with sodium hypochlorite, followed by continuous acidification, skimming, thickening, and sand filtration. The possible methods considered are most easily explained after a discussion of the flow sheet finally chosen for the plant.

Description of the Plant

The flow sheet for waste disposal facilities at the Sherrill plant is presented in Figure 2, to which reference should be made in reading this description. Raw wastes from the factory flow by gravity into the sumps (A, B, C). Each of these sumps has sufficient capacity between the normal operating level and the overflow level to hold the wastes produced in 1 hr. of normal factory operation. This reserve capacity is estimated to be more than enough to permit complete drainage of the waste collecting lines in the factory in the event of a complete power failure. As a further precaution the overflows from the sumps are routed to a permanent lagoon area to provide for the possibility of a complete shutdown of waste disposal facilities while the factory is in normal operation. Skimmings from the alkali sump are drained to the lagoon periodically by the simple expedient of allowing the level of the liquids in this sump to rise to the overflow mark. The wastes are removed from each sump by pumps operated from liquid level controls.

Silver-Bearing Wastes

Silver-bearing wastes are transferred by pumps e to either of the 10,000-gal. tanks R–1 and R–2, each of which has sufficient capacity to hold the silver-bearing wastes from two days of normal factory operation. After a tank has been filled, the flow is switched to the other tank, and the pH of the contents of the filled tank is adjusted to about 8.5 by the addition of acid. Sodium hypochlorite is then added in sufficient quantity to supply 8.5 lb. available chlorine per pound of cyanide. As noted in Part II, the oxidation of cya-

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† Present address: Oneida, Ltd., Oneida, N. Y.

‡ Parts I and II of this series were published in This Journal, **26**, 7, 843 (July, 1954).

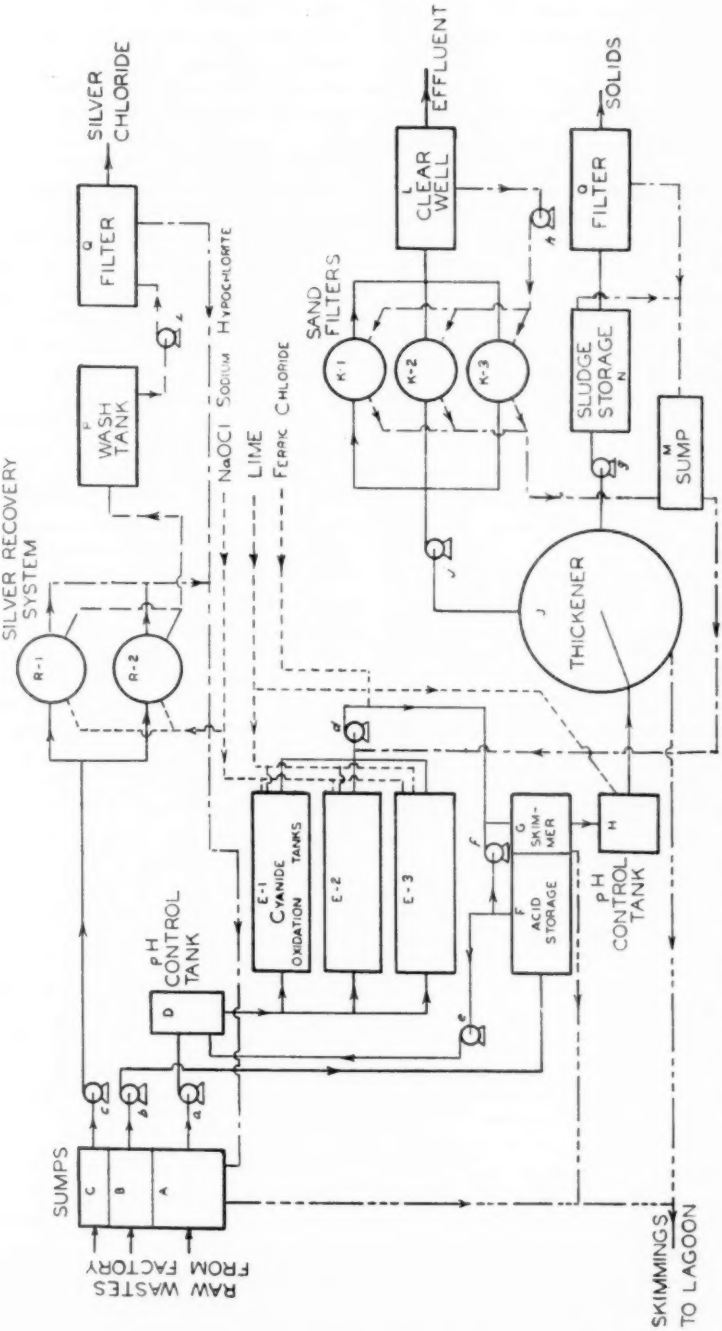

FIGURE 2.—Flow diagram of wastes treatment at the Sherrill, N. Y., plant of Oneida, Ltd.

nide under these conditions may be expected to be reasonably complete after 2 hr.

At the end of this time the agitator is stopped and the tank contents are allowed to stand overnight. The supernatant liquid is then drained into the alkali sump to avoid the necessity for careful adjustment of the composition of this small stream (about 2 to 3 per cent of the total flow of wastes). The silver chloride is allowed to accumulate in the tank through several batches to maintain a precipitate of good settling characteristics. Periodically part of the silver chloride slurry in a tank is transferred by gravity to the wash tank (P) and is subsequently recovered on a filter (Q), the filtrate being drained back to the alkali sump.

Acid Wastes

Acid wastes are transferred by pump b to the 54,000-gal. storage tank F. This tank has more than enough capacity to hold the acid wastes produced in one day of factory operations, the size being determined by the desirability of equalizing the composition of the acid wastes and the necessity for utilizing in 16 hr. the acid wastes collected in 8 hr. Acid wastes are removed from tank F by pumps e to be used to regulate the pH of incoming alkali wastes and by pumps f to be mixed with alkali wastes to lower the pH for skimming in G and to provide heavy metals for floc formation.

Alkali Wastes

Alkali wastes are transferred by pumps a through the 1,000-gal. tank D, where acid wastes are added under automatic control to regulate the pH at about 8.5, and thence to one of the 80,000-gal. tanks E–1, E–2, E–3. After a tank is filled, the flow is switched to the next tank in sequence, and sodium hypochlorite is added to the contents of the filled tank in sufficient amount for complete oxidation of the cyanide. The oxidation of the cyanide is complete in about 2 hr. The contents of tanks E are transferred through pumps d to the skimmer G. It is possible to maintain essentially a continuous flow from the tanks E during the operating day by manual setting of a flow controller in the line from E.

Acid wastes are added to the partially treated alkali wastes flow in the line between tanks E and skimmer G. If the acid wastes available do not result in a pH low enough for efficient skimming or in a heavy metals concentration high enough to provide an adequate floc for clarification, it becomes necessary to use ferric chloride. Skimmings from tank G flow by gravity to the permanent lagoon area. The main wastes from tank G flow by gravity to the 1,000-gal. tank H, where lime slurry is added under automatic control to raise the pH to about 8. The mixture then flows to a thickener J, from which there are removed: (a) skimmings from the top, these being transferred to a sump and thence by pump to the lagoon area; (b) sludge from the bottom, being transferred to a sump and thence by pump to a storage tank N; and (c) clear effluent from a submerged discharge, being transferred to a sump and thence by pump to sand filters K–1, K–2, K–3. Water from the clear well L is used for backwashing the sand filters and is then recycled to the process. The sludge from tank N is processed on a rotary vacuum filter O, the cake being discharged to the lagoon area and the filtrate recycled to process. The overflow from the clear well L is mixed with clean water discharged from the factory and the mixture flows into Seconondoa Creek.

Chemical Supply System

The chemical supply system is not shown on the flow sheet. Ferric chloride is purchased in 100-lb. drums and made up as a 10 per cent solution. Lime is purchased as the hydrate in 50-lb. paper bags, which are emptied

by hand into a lime hopper on the second floor of the operating building. The supply of 10 per cent lime slurry is automatically maintained by the use of a feeder controlled by the liquid level of the lime slurry reservoir.

Sodium hypochlorite is prepared in the plant from chlorine, which is purchased in 1-ton cylinders, and caustic soda, which is purchased in 400-lb. drums. The equipment for making up hypochlorite consists of a chlorinator, a 1,000-gal. steel tank equipped with stirrer and heat exchanger for making up and cooling caustic soda solution, two 1,000-gal. rubber-lined steel tanks for storage of hypochlorite and a heat exchanger. Cooled caustic soda solution is transferred to one of the hypochlorite tanks, from which it is cycled through the chlorinator and heat exchanger continuously until the required amount of chlorine has been added.

The use of hypochlorite solution in preference to chlorine was indicated in this plant by two factors. For one thing, the alkali wastes contain too much suspended matter to permit passing them through the injector of a chlorinator, thus making it necessary to supply water for carrying the chlorine. Secondly, the usage of chlorine on Friday is more than 20 times as great as on other days of the operating week, leading to a large spread in the chlorine feed rates required. This large spread in feed rates is not a difficult problem when sodium hypochlorite is used, but requires the use of either a very large chlorinator or a very long time for chlorine addition on Fridays if a chlorinator is used.

Construction Materials

Most of the reaction tanks are constructed of concrete. Tanks R are lined with Resilon. Tanks, F, G, and B are lined with Resilon and acidproof brick. Tanks D and H and the hypochlorite and ferric chloride storage tanks are lined with rubber. Steel piping is used except where acid or hypochlorite concentrations are too high; in these cases Saran-lined steel pipe is used for pipes greater than 1-in. diameter, and polyvinyl chloride pipe for smaller pipes. Pumps are all-iron except where acid concentrations indicated the use of Duriron or hypochlorite concentrations indicated the use of Durichlor.

The actual layout of the plant is depicted in Figure 3. This is self-ex-

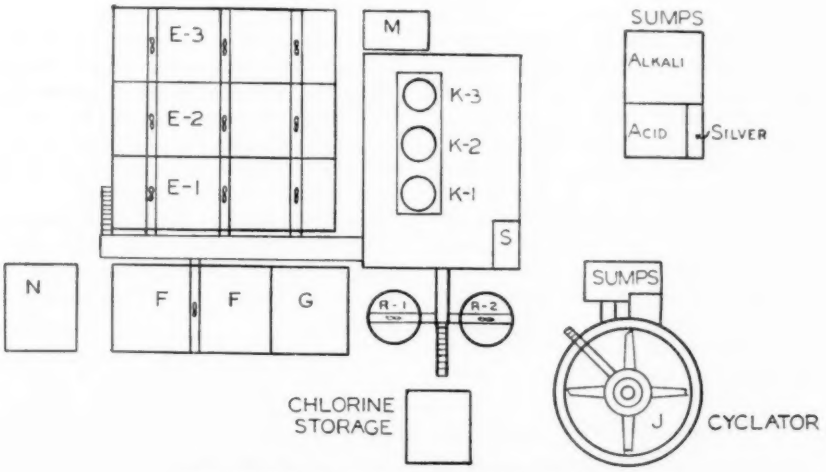

FIGURE 3.—Layout of wastes treatment plant.

TABLE VIII.—Outline of Waste Treatment Control System

Control	Location	Alarm	Indicating	Recording	Controlling
Liquid level	Sump A	High	x		Pumps a, throttle valve
	Sump B	High			Pumps b
	Sump C	High			Pumps c
	Tanks R	High	x		
	Tanks E[1]	High, low	x		Inlet valves (high level)[1]; Outlet valves and pumps (low level)[1]
	Tank F	High, low	x		
	Tank M		x		
	Cyclator J:				
	Effluent sump	High			Pumps j; variable flow rate controllers on sand filters
	Sludge sump	High			Pumps g
	Skim sump	High			Pumps
	Sand filters[2]				Effluent valve settings
	Clear well[2]	Low			
	Hypochlorite tank[1]	Low			
	Lime slurry tank	High, low			Lime feeder; water supply
pH	Tank D	High, low	x	x	Throttle valve in acid feed line
	Tank G	High, low		x	
	Tank H	High, low	x	x	Throttle valve in acid feed line
	Cyclator J	High, low		x	
	Clear well	High, low		x	
Flow rate	Alkali wastes to G		x		
	Acid wastes to G		x		
	Effluent to ditch			x	
Head loss	Sand filters[3]	High	x		Back wash cycle[2]

Notes on interlocks:

[1] High level in E-1, E-2, or E-3 causes inlet valve to close and inlet valve on next tank in sequence to open. Drainage of E-1, E-2, or E-3 is initiated by push button which opens selected tank outlet valve and starts pumps d and f. Inlet valve and hypochlorite valve cannot open when tank is draining. Outlet valve cannot open until hypochlorite valve has been actuated. Low level in E-1, E-2, or E-3 closes outlet valves and stops pumps d and f.

[2] Backwash cycle cannot be started if liquid level in clear well is too low.

planatory as regards the equipment located outdoors. The first floor of the operating building houses pumps, chemical supply tanks (including the hypochlorite preparation system), and the sand filter, as well as valve stations for lines to tanks E, F, G, and R. Half of the second floor is devoted to a control laboratory and operating room. The other half of the second floor is used for storage of lime, ferric chloride, and caustic soda, this area being located directly above the chemical supply tanks on the first floor.

Control System

The problem of a control system for a waste disposal plant must be considered from the usual viewpoint of the savings in labor costs which result from the use of controls and from the viewpoint of providing the operators with a plant in which the probability of serious mistakes is as low as it is economically feasible to provide.

In this case it was considered first that the process was sufficiently complex to justify the following simply in terms of safety and the operators' morale:

1. Provision is made for operating the major valves and motors from a central location in the operating building.

2. Valve and meter switches are mounted on a graphic panel, along with

other equipment, to aid the operator in visualizing the process.

Once it was decided to provide these features, a further study was made of the feasibility of providing certain automatic controls. It was considered essential that liquid level controls be provided in several sumps because of the great difficulty that would have been encountered in any attempt to set flow rates by manual controls. Automatic control of pH in the alkali waste leaving tank D and in the combined wastes leaving tank H was considered essential because the success of the chemical treatments depends on the regulation of these pH values, the first providing the optimum pH for cyanide oxidation and the second the optimum pH for heavy metals removal. Consideration of the operators' time indicated the advisability of providing automatic control of the distribution of liquid over the sand filters and of the backwash cycle on these filters. An outline of the resulting control system is presented in Table VIII.

Alternative Flow Sheets Considered

In arriving at the decision to use the flow sheet depicted in Figure 2 it was necessary to evaluate several other possibilities first. In particular, it was desired to compare batch and continuous operations and to determine the optimum number of hours of operation per day. Preliminary cost estimates were therefore prepared for the following cases:

Scheme 1.—A complete batch scheme of treatment was considered; that is, provision was made to accumulate the alkali wastes in large tanks where hypochlorite would be added for cyanide oxidation, followed by acidification with acid wastes or ferric chloride, skimming, treatment with lime, allowing to stand for settling of the floc, and decanting of the supernatant to sand filters. Provision was made for two 80,000-gal. treatment tanks lined with acid-proof brick and a large concrete storage tank for accumulation of wastes in excess of the treatment rate on the day shift.

Scheme 2.—The treatment scheme considered in this case was identical with that of Scheme 1. However, provision was made for three 80,000-gal. treatment tanks in order that the treatment could be carried out in 16 hr. per day. This eliminated the necessity for the concrete storage tank of Scheme 1.

Scheme 3.—A complete continuous scheme of treatment of alkali and acid wastes was considered, with provision being made for equalizing flow rates and compositions by the use of storage tanks for the raw wastes. It was proposed to carry out the cyanide oxidation by adding hypochlorite in the required quantity to the alkali waste

TABLE IX.—Alternatives Considered in Wastes Treatment Plant Design

Scheme	Cyanide Oxidation	Skimming and Precipitation	Operating Time (hr./day)	Ultimate Capacity (g.p.d.)	Costs[1] ($)	
					Capital	Annual Operating
1	Batch	Batch	24	480,000	40,000	2,700
2	Batch	Batch	16	480,000	56,000	6,700
3a	Continuous	Continuous	8	960,000	26,000	8,000
3b	Continuous	Continuous	16	480,000	6,000	4,000
3c	Continuous	Continuous	24	320,000	0	0
4a	Batch	Continuous	8	960,000	40,000	8,000
4b	Batch	Continuous	16	480,000	15,000	4,000
4c	Batch	Continuous	24	320,000	9,000	0

[1] Referred to Scheme 3c as basis.

flow from the equalizing tank, holding the waste in an agitated tank for 20 min. for oxidation of cyanide to cyanate, and pumping to a second hold-up tank maintained at pH 6.5 for rapid oxidation of cyanate to carbon dioxide and nitrogen (20 min.) This was to be followed by continuous acidification, skimming, lime addition, thickening, and sand filtration.

Scheme 4.—In this scheme provision was made for batch oxidation of cyanides followed by continuous acidification, skimming, lime addition, thickening and sand filtration.

The results of these preliminary cost estimates are presented in Table IX.

It is apparent that the batch plants are appreciably higher in first cost than are the continuous ones, and that they may be ruled out on the basis of this factor alone. Most attractive from the standpoint of first cost is the completely continuous plant (Scheme 3). Of the schemes 3a, 3b, and 3c, it will be apparent that 3b provides a large factor of safety in the ultimate capacity of the plant and yet costs only $6,000 more than 3c. However, batch oxidation of cyanides in a 16-hour-per-day plant (Scheme 4b) can be provided for an additional $9,000. The more positive control of cyanide oxidation which results from use of the batch treatment was considered to be sufficient justification for selecting finally Scheme 4b.

The results of this evaluation should not be used for generalizing on the question of batch *versus* continuous processing. It may be noted in particular that batch processes are ruled out here because the acidification step which precedes skimming makes it necessary that relatively expensive treatment tanks lined with acidproof brick be used. Had the alkali waste not contained organic matter, unlined concrete tanks could have been used and the cost picture would have been more favorable to Schemes 1 and 2.

IV. Treatment of Lagoon Waters

By Charles A. Walker, Paul W. Eichenlaub, and James Cox

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The disposal of liquid wastes by routing them to lagoon areas, depending on evaporation and seepage to limit the lagoon volume required, can seldom be considered as a complete solution to a disposal problem. Limitations on the use of this method are imposed by the necessity for using shallow lagoons of large area to increase the over-all rate of evaporation or depending on seepage for water removal. In the latter case there is assumed some risk of contaminating ground waters. Despite these and other complicating factors, lagooning of liquid wastes is of use as a temporary solution to a problem and may be of use as a permanent solution in cases where waste flow rates are very small compared to the land areas available. As a matter of fact, it may be noted that most waste disposal plants do not eliminate entirely the necessity for lagoon areas, but simply provide for minimizing the problems and risks of lagooning by reducing the volume of materials to be lagooned and by converting toxic materials to insoluble forms which will not be leached into the soil.

When it was decided in 1941 to remove the most seriously contaminated wastes from the plant effluent flowing into Sconondoa Creek, the uncertainty of the times made it necessary to limit the start of the waste disposal program to the development of a new waste segregation system and a system of lagoons for the most heavily contami-

nated wastes. The general description of the waste segregation was presented in Part I. A sketch of the layout of the lagoon system was presented in Figure 1. Raw wastes are routed through Pond 1 into Pond 2, or directly into Pond 2, and thence to Ponds 3 and 4. The mixing of raw wastes in Ponds 1 and 2 results in the precipitation of such materials as heavy metals soaps in these areas. The combined effect of the neutralizing action and "weathering" lead to wastes in Ponds 3 and 4 which are much less concentrated in certain materials than are raw factory wastes.

During the period of 1941–52 the first three of the disposal ponds (with a combined capacity of some 15 m.g.) proved adequate for the disposal of the most seriously contaminated wastes from the plant, the combined effect of seepage and evaporation apparently being sufficient to remove water at a satisfactory rate. Pond 4 (with a capacity of about 10 m.g.) was provided in late 1951, primarily as a matter of insurance. In January 1952, however, it became necessary to route wastes to this pond, and within four months of this time the entire lagoon system had filled to the point where overflow into Sconondoa Creek appeared inevitable. What change in conditions caused this rapid filling of the lagoon system is not known, although it appears most likely that the seepage rate decreased as a result of the sludge blanket accumulating on the bottoms of the lagoons. In any event, it appeared in April 1952 that the lagoons were in serious danger of overflowing within a few weeks or months unless the influent rate could be decreased by treatment of raw factory wastes or the water in the ponds could be purified by chemical treatment to a degree which would permit its discharge into Sconondoa Creek.

It was apparent that considerable time might be saved by erecting the facilities necessary for pond-water treatment rather than for treatment of raw factory wastes because the neutralizing and weathering action in the ponds provided wastes of simpler composition. It was decided to proceed immediately with the design and erection of a plant which could be used to treat water from Pond 3. Fortunately, at the time this decision was made it was possible to plan these facilities in such a way that essentially all of the equipment provided could later be incorporated in the final plant. Furthermore, the erection of these facilities more than a year ahead of the rest of the plant provided the opportunity for large-scale studies of the proposed processes for treating raw factory wastes and for beginning training of personnel.

Operating Procedure and Plant Facilities

The analysis of the water in Pond 3 at the time the waste disposal plant was being planned indicated the presence of 7 p.p.m. copper, 5 p.p.m. nickel, 21 p.p.m. zinc, 5.9 p.p.m. total cyanide, and 80 p.p.m. suspended solids. Laboratory investigations showed that this waste could be converted to a clear liquid with low contents of toxic materials by a procedure similar to that developed for treating raw alkali wastes (see Part II). It was possible to omit the two skimming steps of that procedure, however, since the wastes from the ponds contained little oil and grease. The basic treatment process, therefore, consisted of the following steps:

1. Addition of lime to pH 8–9.
2. Addition of sodium hypochlorite in sufficient quantity to provide 8.5 lb. available chlorine per pound of cyanide.
3. Standing for 10 min. to allow time for cyanide oxidation.
4. Addition of ferric chloride in sufficient quantity to yield 60 p.p.m. Fe. This resulted in a decrease in pH to about 6.5.

5. Standing for 10 min. to allow time for cyanate oxidation.

6. Addition of lime to pH 8–8.5, followed by a settling period of about 1 hr.

7. Decantation of the supernatant liquid to sand filters.

8. Discharge of the sludge blanket to disposal lagoons.

At this stage in the development, plans had proceeded to the point where it appeared that (a) an acidproof brick-lined tank of roughly 75,000- to 100,000-gal. capacity would almost certainly be useful in the final plant, either as a treatment tank for alkali and acid wastes or as a vessel to contain an acid storage tank and a continuous skimmer, and (b) sand filters would almost certainly be necessary in the final plant because of the relatively low dilution factor available during dry seasons. It was not possible to justify the erection of more than one tank at this time. However, considerations of an operating schedule for the pond-water treatment indicated the desirability of providing three treatment tanks in order to maintain a continuous flow of pond water to the plant and of effluent from the plant, thus minimizing the sizes of the pond-water pump and pipe line and of the sand filters. The necessity for a minimum of three tanks is apparent when it is realized that the cycle for handling a single batch consists of filling, treating, and draining. It was relatively simple to provide three tanks in this case by the expedient of constructing a rectangular tank of 81,000-gal. capacity and installing two temporary concrete partitions. The plant facilities depicted in Figure 4 were therefore constructed. It may be noted that tanks A of Figure 4 were later converted to tanks F and G of the complete plant (Figure 2), and that sand filters B and clear well C of Figure 4 are identical with sand filters K and clear well L of the complete plant. Thus the "temporary" portion of the pond-water treatment plant consisted only of the tank partitions, the swing pipes and other piping of tanks A, and the chemical supply system.

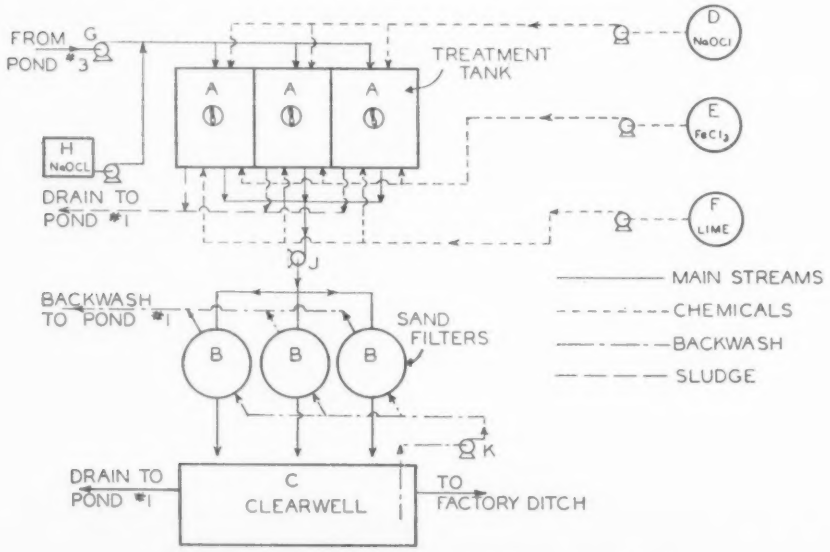

FIGURE 4.—Plant for temporary pond-water treatment.

Treatment Scheme as Modified by Presence of Sulfides

It was noted in the preceding section that the pond-water treatment facilities were planned on the basis of a pond-water composition of 7 p.p.m. copper, 5 p.p.m. nickel, 21 p.p.m. zinc, 5.9 p.p.m. total cyanide, and 80 p.p.m. suspended solids. This represented a typical analysis of Pond 3 water in April 1952. By late May 1952 it was noted that the cyanide content of the pond water had fallen to less than 1 p.p.m., an effect which was assumed to be due to volatilization of hydrogen cyanide occurring as a result of the seasonal increase in temperature of the pond water. There was no occasion for analysing the pond waters again until July 1952, shortly before the pond-water treatment plant was to be put in operation. It was noted in early July that the water in Pond 3 had turned black and exhibited a strong odor of hydrogen sulfide. This occurrence was completely unexpected, because the waste disposal ponds had been in existence for some eleven years and had not shown evidence of sulfides in previous summers. It was realized that the sulfide in the pond could not possibly enter through the raw factory wastes, as the sulfide usage in the Sherrill plant is small. Furthermore, it was obvious that the action was at first confined to Pond 3, although it later spread to Pond 4. It appeared, then, that the only feasible source of the hydrogen sulfide was bacterial, certain strains of anaerobic bacteria being known to utilize oxygen from sulfates in their life processes and thus reduce sulfates to sulfides. This conjecture was later confirmed by the identification of *Sporovibrio desulfuricans* as the bacterial strain responsible for the presence of sulfides. Thus it became known two weeks before the pond-water treatment was initiated that the water in Pond 3 contained relatively high concentrations of sulfides, but essentially no cyanide. It was realized that the treatment scheme would have to be modified to convert the sulfides to less objectionable materials from the standpoints of toxicity and foul odor. It might be supposed that under these conditions hydrogen sulfide would precipitate copper, nickel, and zinc. The metals were converted to the insoluble sulfides, but remained suspended in the water.

It was indeed fortunate that this major change in water composition required essentially no change in treatment processes, as sodium hypochlorite will oxidize sulfides to the harmless sulfates as efficiently and as rapidly as it will oxidize cyanides. The only appreciable change in operating procedure was simply an increase in the sodium hypochlorite dosage. The quantity of this chemical to be added was determined in the laboratory by treating a batch of pond water with a known amount of sodium hypochlorite and then titrating the excess available chlorine. Analytical data on the sulfate and chloride contents of Pond 3 water before and after treatment with sodium hypochlorite indicated clearly that the oxidation of sulfides occurs as indicated by

$$S^{=} + 4NaOCl \rightarrow SO_4^{=} + 4NaCl.$$

These data also indicated that some hypochlorite reacted with materials other than sulfide in the pond water; that is, the chlorine demand of the pond water was greater than that due to sulfide alone. This additional chlorine demand was indicated to be due to organic matter by the fact that the extra chlorine consumed did not appear as chloride in the supernatant liquid. It was further shown that the oxidation of sulfides occurred much more rapidly than the reaction between chlorine and organic matter. Thus an operating scheme which yielded an effluent with a slight chlorine demand was considered to be desirable in that it avoided

the possibility of excess chlorine in the effluent.

The following procedure for treating the sulfide-bearing waters was therefore used:

1. Samples of the pond water were titrated periodically to determine the chlorine demand. The sodium hypochlorite dosage was then calculated to leave a 10- to 20-p.p.m. chlorine demand in the treated water. The calculated quantity of sodium hypochlorite was then added and the batch was allowed to stand for 10 min. to insure adequate time for reaction.

2. A solution of ferric chloride was added in sufficient quantity to yield 60 p.p.m. iron in the pond water.

3. Lime slurry was added to pH 8 and the resulting floc was allowed to settle.

4. The supernatant liquid was titrated to check the hypochlorite dosage. A chlorine demand of 0 to 20 p.p.m. was considered satisfactory.

5. The supernatant liquid was sand filtered. Numerous analyses of the clear well liquid during the period this scheme was in use indicated the presence of about 1 p.p.m. copper, 0.5 p.p.m. nickel, and 2.5 p.p.m. zinc. The dilution factor available was adequate to reduce these concentrations approximately 10-fold.

One other serious problem arose in connection with the treatment of sulfide-bearing waters. When the black water from Pond 3 was pumped into a treatment tank and agitated, a strong odor of hydrogen sulfide was noted. This odor is very objectionable and gave cause for concern because of the toxicity of hydrogen sulfide. It was further feared that hydrogen sulfide might be carried in the air to manufacturing areas and cause serious trouble by tarnishing silver. A simple solution was found to this problem in that injection of sodium hypochlorite into the pond water just as it entered the pipe line resulted in sufficient reaction within the pipe line to provide complete removal of odor before the water entered the reaction tanks. It was necessary only to build a concrete hypochlorite storage tank and install a small proportioning pump near Pond 3. This procedure probably resulted in accelerated corrosion of the pipe line but this was considered to be a small price to pay for the solution to the problem.

The treatment scheme for sulfide-bearing waters as outlined was used during the period July–October 1952. By late August it was apparent that the bacterial activity in the ponds had dropped to a low level, apparently as a result of exhaustion of the sulfate supply in the slime layer on the pond bottoms. This decrease in bacterial activity was followed by a marked decrease in the concentration of free sulfides in the pond water, but the concentrations of metallic sulfides remained at relatively high values for some weeks.

Treatment Scheme as Modified for Cold-Weather Operation

In late October the treatment plant was shut down for about five weeks to permit the erection of sheds over the sand filters and to make other provisions necessary for cold-weather operation. Shortly before operation of the plant was resumed in early December analysis of a sample of pond water revealed that the sulfide content had fallen to a negligible value and the cyanide content had risen to about 4 p.p.m. The necessity for treating this water at a temperature of 32° to 35° F. led to a brief laboratory investigation, conducted with 1-l. batches of the pond water at 33° F., the results of which indicated that even at this temperature the reaction between cyanide and hypochlorite is rapid. It was further indicated that the metal hydroxide floc settled at a satisfactory rate in spite of the increased viscosity of the

solution. On the basis of this brief investigation it was decided that little change in operating procedure was necessary.

However, when the pond-water treatment process was started again it became immediately apparent that the laboratory investigations had failed to reveal one difficulty in the low-temperature treatment. This difficulty lay in the fact that the lowered temperature of the operation resulted in a much lower rate of cyanogen chloride hydrolysis, with the result that the very toxic fumes of this material were noted around the treatment plant, particularly in the shed erected over the sand filters. The chemical reactions which occur in the first stage of the oxidation of cyanide by sodium hypochlorite may be represented as follows:

$$CN^- + NaOCl + H_2O \rightarrow CNCl + Na^+ + 2OH^- \quad \ldots . (1)$$

$$CNCl + OH^- \rightarrow CNO^- + H^+ + Cl^- \quad \ldots . (2)$$

The laboratory investigations noted above showed merely that reaction (1) is rapid even at 33° F. but failed to reveal the marked effect of temperature on the rate of reaction 2.

Eden and Wheatland (7) studied the effect of temperature on the rate of reaction 2. Their results showed the following points of interest as related to this work:

1. The half-life of cyanogen chloride is increased approximately 30-fold as the temperature is decreased from 20° C. to 0° C. Thus, whereas the hydrolysis of cyanogen chloride is substantially complete in 10 min. at 20° C., a period of several hours is required for its completion at 0° C.

2. The rate of cyanogen chloride hydrolysis is a marked function of the concentration of excess chlorine. Thus, with 20 p.p.m. excess chlorine present the hydrolysis is substantially complete in 10 min., even at a temperature of 0° C.

3. The rate of reaction 2 is a function of pH, being more rapid at high pH values.

These results indicated clearly that the problem of cyanogen chloride could be solved by maintaining a high pH and using excess chlorine. In plant practice the excess of chlorine was destroyed by the addition of sodium bisulfite just before each batch was allowed to settle. The treatment scheme previously outlined was therefore changed only in that lime was added to the raw waste to pH 9.5 before the hypochlorite was added and a definite excess of chlorine was maintained. Extensive analytical data on the water in the clear well showed that the effluents from this treatment method contained about 0.5 p.p.m. copper, 0.5 p.p.m. nickel, and 2.5 p.p.m. zinc.

Reference

7. Eden, G. E., and Wheatland, A. B., "Effect of Temperature and Presence of Hypochlorite on the Rate of Hydrolysis of Cyanogen Chloride in Alkaline Solution." *Jour. Soc. Chem. Ind.*, **69**, 166 (June, 1950).

DESIGN AND OPERATION OF A PHENOL RECOVERY PLANT *

By James C. McCord

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The Bethlehem Steel Co. coke plant at Lackawanna, N. Y., consists of 459 by-product coke ovens arranged in seven batteries, with a maximum carbonizing capacity of 8,800 tons of dry coal per day, producing 6,500 tons of coke. The ammonia liquor produced during coking amounts to approximately 15 to 20 gal. per ton of dry coal, depending on the amount of free and inherent moisture in the coal as charged. It is obtained, along with the tar, as a condensation product from the collecting mains and direct-type primary coolers through which the foul gases from the ovens pass. This liquor contains dissolved gases, fixed and free ammonium salts, and, in addition, phenolic-type organic compounds, the amount and composition of which, in both the tar and weak liquor, are functions of the type of coals carbonized, the coking rates, and the temperature of the oven operation.

The addition of the seventh battery of ovens at Lackawanna necessitated an increase in the capacity of the by-product equipment. At that time, therefore, it was decided to replace the existing antiquated dephenolizing plant with a light oil, or benzol, absorption-type plant of adequate capacity and modern design. Since an increase in liquor storage capacity was required, it was believed that an advantage of this type of plant would be that it could operate as a separate continuous unit with storage capacity for both phenolized and dephenolized liquor. A leading builder of coke plant equipment was awarded the contract for the engineering and construction of these by-product plant additions, including the dephenolizing plant.

Recovery Process

The light oil, or benzol, absorption-type plant for the treatment of ammonia liquor is not new and has been described in previous literature. Essentially the plant comprises two liquid-liquid extraction processes, operating in series, involving immiscible liquid phases of differing densities. In the first step, phenolized ammonia liquor and dephenolized light oil goes to a continuous counter-current contact tower of the packed type, in which the phenols in the ammonia liquor are absorbed by the light oil, and from which the weak dephenolized ammonia liquor is returned for further processing to recover the ammonia. The second step is the chemical extraction of the phenols from the phenolized light oil in a two-stage contact tower of the packed type by a solution of sodium hydroxide to produce sodium phenolate. The light oil, or benzol, recycles through both contacting towers and thus acts as a carrier medium by which the phenols are removed from ammonia liquor and are converted to a saleable product.

The efficiency of extraction equipment of this type is primarily a matter of design to obtain the highest possible intimacy of contact, and contact area, between the two liquids. Particle dispersion of the entering liquid streams

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and the location, type, and amount of tower packing are of great importance. Sufficient contact time of the liquid phases must be allowed for, although this is not as great a factor in the light oil-caustic contactors because the reaction is fast and non-reversible. The efficiency of operation is affected by the densities and viscosities of both liquids, which in turn vary with temperature and liquid stream composition. It should be noted that the term "phenols," as it is used here, refers to the entire group of homologous organic compounds of which phenol is a member, and that analytical results as reported are generally phenol equivalents. The efficiency of the extraction equipment can also be affected by variations in the composition of the phenols to the absorbed. The contacting towers include decantation sections for both liquid streams, and these must be properly designed to prevent entrainment, which would greatly reduce process efficiency.

Description of Plant

The process and major physical dimensions of the equipment can be described by using the flow diagram of the dephenolizing plant (Figure 1). The phenolized ammonia liquor is pumped from storage tanks to the ammonia liquor-light oil treatment tower, passing first through three porous stone filters, each of 3,500-g.p.h. capacity. These filters, which are of the automatic backflushing type, remove suspended solids and tars from the liquor, which would interfere with the treatment tower operation. From the filters, the liquor passes through two water-cooled shell-and-tube coolers, which can be operated in series or in parallel, and thence to the ammonia liquor-light oil treatment tower. This tower is 10-ft. inside diameter, 80 ft. high, and has the outside insulated with ¼ to ⅜ in. of insulating mastic to maintain a constant tower temperature. The filter phenolized liquor enters at a point 14.5 ft. from the top of the tower and flows down the tower counter-current to a stream of dephenolized light oil, which enters at a point 14.5 ft. from the bottom and passes up to the top overflow. The contact efficiency of this tower is obtained by the use of inlet pipe distributing headers having a large number of drilled orifices, and also by six tower packing sections, two being wood hurdles and four being ceramic tower packing. The dephenolized liquor leaves the bottom of the tower through an adjustable seal and flows to a dephenolized liquor storage tank, from which it is pumped for further processing.

The phenolized light oil, after leaving the liquor-light oil treatment tower, enters the sulfur scrubber, which is the top section of the light oil-caustic treatment tower. This tower is 10-ft. inside diameter by 73 ft. high, insulated with 1½-in. magnesium block to reduce heat losses, and is divided into four practically equal sections, the top three of which are scrubbers. The efficiency of these contacting sections is obtained by the use of pipe distributing headers and a layer of ceramic packing in each section. In the sulfur scrubber the phenolized light oil flows counter-current to a stream of fresh water entering near the top, and this water, containing a portion of the hydrogen sulfide from the light oil, is sealed from the bottom to be used as make-up in the final cooler recirculating system, which is a completely closed circuit.

The phenolized light oil from the top of the sulfur scrubber flows up through the caustic solutions of both scrubbers in series, which extracts the phenols from the light oil. The dephenolized light oil enters the light oil circulation tank for recycling in the system; this tank also serves as a decanter for entrained caustic, which can be returned to the No. 2 scrubber. Fresh light oil is added to the system

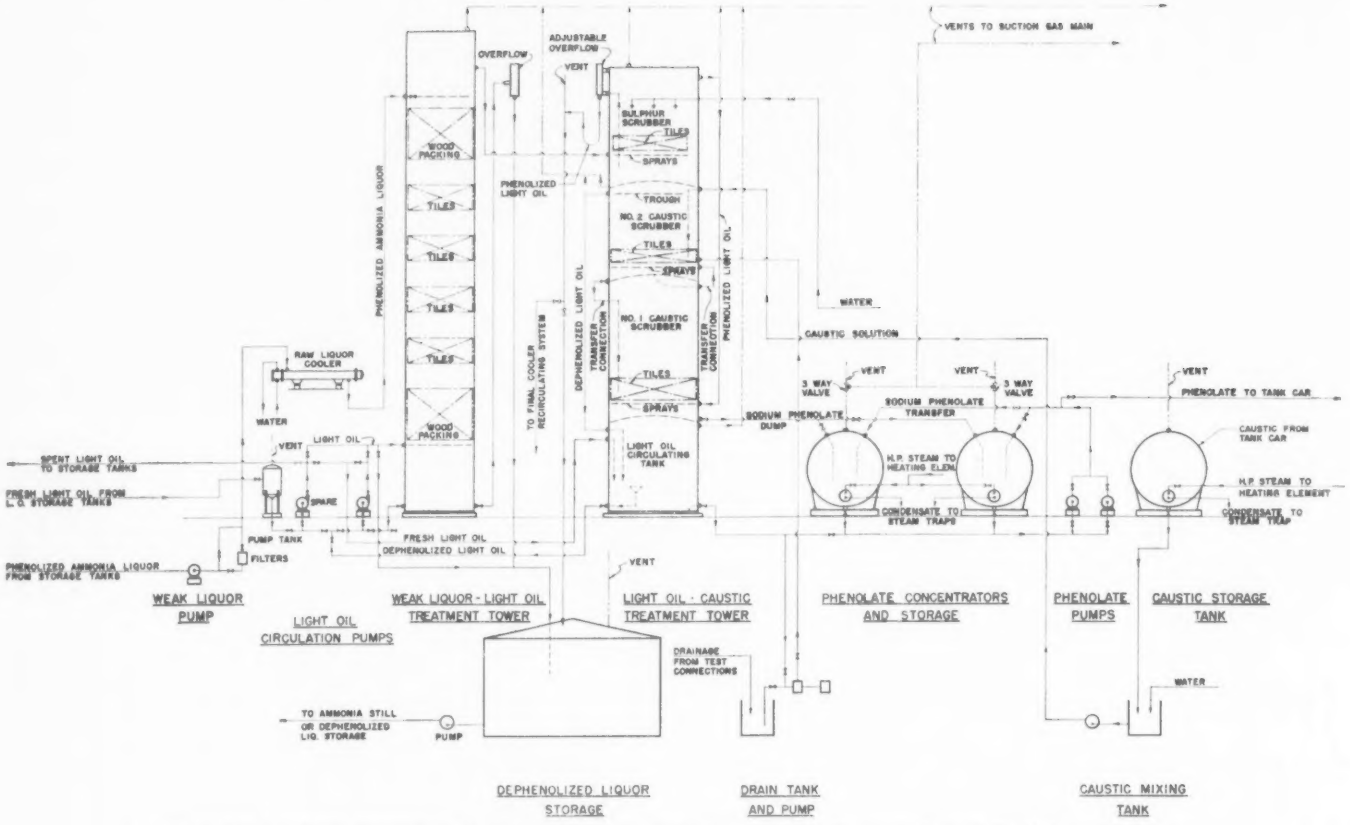

FIGURE 1.—Flow diagram of dephenolizing plant at Lackawanna, N. Y., coke plant of Bethlehem Steel Co.

from a pump tank of approximately 3,000-gal. capacity which is filled with light oil from storage tanks at the benzol plant, to which the spent light oil can be returned. The major portion of the phenols from the circulating light oil is extracted by the caustic solution in the No. 1 scrubber, and when this charge becomes spent it is dropped to the phenolate concentrators; the No. 2 scrubber charge is dropped to the No. 1 section, and a fresh charge of caustic is pumped to the No. 2 scrubber. The fresh caustic solution (250 grams per liter NaOH) is prepared in a mixing tank using 50 per cent liquid caustic. The plant is shut down during this operation, which takes from 3 to 4 hr.

The three phenolate concentrator tanks, each of 20,000-gal. capacity, are used to prepare the phenolate as a shipment product. This treatment takes place in two steps. First, the phenolate is carefully heated using indirect and direct steam to drive off any light oil, or naphthalene, contained in the charge with the tanks vented to the oven suction mains. The second step consists of further concentrating with direct and indirect steam, with the tanks vented to the atmosphere, to reduce the water content of the phenolate. All the major parts of the equipment are vented back to the oven suction mains to prevent light oil losses. The drainage liquid from test connections and pumps is collected in a drain tank and pumped back to the system so that no outside contamination will occur from this plant.

This plant was built in the spring of 1953, and it would be well to point out that, from a safety standpoint, the plant should be treated the same as the benzol refining plant, due to the

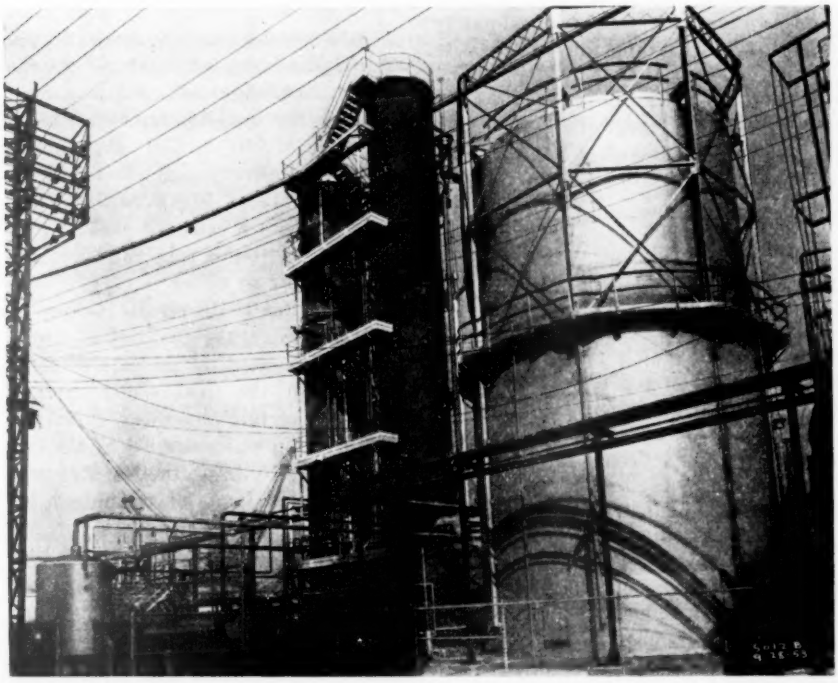

FIGURE 2.—Dephenolizing utilizes counter-current, ceramic packed scrubber and contact towers of light-oil process type.

TABLE I.—Operating and Analytical Data for Dephenolizing Plant

Item	Average
Ammonia liquor flow rate (g.p.h.)	6,000
Light oil flow rate (g.p.h.)	9,000
Temperature (° C.):	
Ammonia liquor to coolers	51.2
Ammonia liquor to tower	36.0
Ht. of ammonia liquor in tower (ft.)	33.4
Phenols in ammonia liquor (p.p.m.):	
Into tower	1,444
Out of tower	17
Removal efficiency (%)	98.8
Caustic scrubber No. 1:	
Free NaOH, 0 hr. (g./l.)	253
Free NaOH, 48 hr. (g./l.)	52
Total NaOH, 0 hr. (g.p.l.)	264
Total NaOH, 48 hr. (g.p.l.)	162
Caustic scrubber No. 2:	
Free NaOH, 0 hr. (g./l.)	288
Free NaOH, 48 hr. (g./l.)	229
Total NaOH, 0 hr. (g./l.)	289
Total NaOH, 48 hr. (g./l.)	253

large amount of light oil handled. In this case the plant is located at some distance from the benzol plant to obtain proximity to the ammonia still operation, and the area is completely fenced and restricted (Figure 2).

Operation

The plant was put in service on July 7, 1953, and has been in continuous operation since that time, during which the operating rate of the coke plant at Lackawanna has been approximately 6,000 tons of coke per day. This rate has limited operation of the dephenolizing plant to a maximum rate of 7,000 g.p.h., with an average of 129,400 g.p.d. of phenolized ammonia liquor processed, and an average phenol removal efficiency of 98 per cent in the dephenolizing equipment. The analytical procedure for phenol determinations was changed on November 3, from the Shaw turbidimetric method of the 4-aminoantipyrene (D.A.A.P.) colorimetric system, which gave results generally below 30 p.p.m. and a better picture of the operation. The best illustration of the operation of the plant can be obtained from the operating data over a 4-day period (Table I) after the plant had been operating several months.

The foregoing results indicate an excellent efficiency of phenol removal at a rate which is, however, only 60 per cent of the designed capacity. The phenol absorbed in the caustic scrubbers is the equivalent of the difference between the free and total NaOH. It is believed that a continuous performance of this efficiency can be obtained at higher flow rates, depending on the maintenance of mechanical equipment and proper operating conditions. One of the major causes of decreased efficiency in the contact towers is the formation of emulsions, resulting in packing and line blockage. These emulsions are apparently formed by by the absorption of heavy tarry substances in the circulating light oil, which can be prevented by good filter operation and a continuous withdrawal and replacement of light oil in the system. The light oil used is a forerunning-free washing fraction with a dry point of 140° to 150° C., containing very little heavy ends. Replacement is at the rate of 10,000 to 2,000 gal. per week with a constant check on oil conditions. At this time the operation of the sulfur scrubber is of questionable value due to the phenol pick-up of the wash water, the quantity of which is greatly limited by the safe disposal capacity in the final cooler system. There is a certain amount of entrained and dissolved water carried by the circulating light oil into the No. 1 caustic scrubber; this can be minimized by elimination of emulsions and proper temperature control to obtain the best possible specific gravities of the contacting liquids. The ratio of light oil flow to liquor flow now in use is 1 to 1.5 and this, as well as other operating conditions, could possibly be changed in the plant with no efficiency loss, but

this is a matter that requires future experience.

Good results have been obtained with a free NaOH concentration in the No. 1 scrubber down to 10 to 15 grams per liter, but operating practice has been to recharge when the No. 2 scrubber begins to show a phenol pick-up as determined by the operator who runs a daily test on the scrubber solutions for volume per cent of wet phenols. The original scrubber charge, approximately 4,500 gal. of 250-g.-per-l. NaOH solution, almost doubles in volume from phenols and water pick-up, but the concentrated shipment phenolate analyzes 50 to 55 per cent dry tar acids and 250 to 275 g. per liter of free NaOH. At Lackawanna, the operator of the dephenolizing plant also operates the ammonia stills, but the labor, power, steam, maintenance, material, and amortization costs are more than the value of the product. The amount of the loss incurred by this operation depends mainly on the factors that govern the sale of the phenolate produced.

At the Lackawanna coke plant ammonia liquor has been dephenolized since 1929. This paper has discussed in detail the operation of the new equipment installed to give a better operating plant.

USPHS SANITARY ENGINEERING TRAINING PROGRAMS

In a recent announcement, the Sanitary Engineering Center of the U. S. Public Health Service outlined a series of training programs to be given during the period July 1, 1954 to June 30, 1955.

Advanced sanitation training courses to be offered include the following:

Sept. 29–Oct. 1, 1954	Seminar on Individual Household Sewage Disposal Systems
Nov. 29–Dec. 10, 1954	Advanced Training for Sanitary Chemists in Water Pollution Investigations
Jan. 10–14, 1955	New Techniques in the Bacteriological Examination of Water
Feb. 16–18, 1955	Short Course in Phenol Determination
Mar. 7–18, 1955	Advanced Training for Sanitary Engineers in Water Pollution Abatement Programs
May 16–20, 1955	Aquatic Biology Training
May 23–25, 1955	Bioassay of Industrial Wastes
June 6–10, 1955	Short Course in Air Pollution Problems

Additional information about these and other courses to be offered by the Sanitary Engineering Center during the next fiscal year may be secured by writing to the officer in charge, Sanitary Engineering Center, Cincinnati 26, Ohio, or through any USPHS Regional Office.

Stream Pollution

ANIMAL PARASITES IN SEWAGE AND IRRIGATION WATER

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The efficiency of sewage treatment in the removal of animal parasites was investigated under experimental conditions by Cram (2), who concluded that primary settling did not remove cysts of *End. histolytica* from sewage; hookworm and *Ascaris* ova settled out better than the cysts, but were still present in the effluent. Furthermore, the experiments indicated that cysts and ova may pass through trickling filters and would survive through activated sludge treatment. Alum flocculation during secondary settling or intermittent sand filtration removed both cysts and ova.

Newton, Bennett, and Figgat (8) studied the effects of various pilot treatment processes upon eggs of *Taenea saginata*. Their results indicated that sedimentation at moderate overflow rates of 1 to 2 hr. would remove the majority of the eggs, but a significant percentage of eggs still would appear in the effluent. In two experiments, 30 and 38 per cent of the eggs passed through a trickling filter operated at slow rates. Activated sludge processing showed little effect upon the eggs except for slow reduction in numbers in the effluent; indeed there was no noticeable effect upon the eggs after five months of aeration. For sand filtration, a glass cylinder, 2.4 in. in diameter and 15.7 in. in length, containing a 12-in. column of sand having a 0.5-mm. effective size and 2.2 uniformity coefficient, was used. This process, at a rate of 1 m.g.a.d., removed eggs completely in three out of four experiments, and 99.6 per cent were removed in the fourth. This indicated that sand filtration would be an effective method for the removal of *Taenea* eggs from primary effluent.

Thus, sewage treatment processes ordinarily used, with the exception of sand filtration, probably are not efficient in the removal of protozoan cysts and helminth ova. This raises the question of the public health hazard in using such effluents for the irrigation of vegetables which are consumed raw or inadequately cooked.

Among the studies of the resistance of protozoan cysts and helminth ova, Rudolfs, Falk, and Ragotzkie (10) (11) made laboratory and field studies on the survival of *End. histolytica* cysts and *Ascaris suum* ova on artificially-contaminated vegetables. Viable cysts could be recovered after 42 hr. when the soil was wet, from both the artificially-contaminated soil and from tomatoes set in a depression of this soil. In the summer, however, when the soil was dry, viable cysts were recovered after 18 hr. from tomatoes only. Viable cysts were recovered from lettuce sampled after 18-hr. exposure when the soil was wet, but from none of the plants sampled after 18-hr. exposure in dry soil. They concluded that field-grown crops contaminated with cysts of *End. histolytica* would be safe for

consumption raw in the temperate zone one week after contamination had stopped and two weeks in the wetter tropics.

In their experiments with *A. suum* eggs, plants and fruits contaminated with eggs and feces were harvested at 13-, 19-, 27-, and 35-day intervals and examined for the recovery of ova. The results showed a great reduction in numbers of eggs, but not at such a rate that the plant would free itself of the eggs in one month. However, development of the ova was greatly retarded, and all eggs degenerated after 27 to 35 days and were incapable of development into the infective stage. They pointed out that these experiments were conducted under dry, hot summer conditions; whether or not similar results could be obtained under moister conditions was open to question.

In the western states many vegetables are customarily irrigated several times weekly until the day of harvest. Therefore, these vegetables might carry viable ova and cysts. The present paper reports the incidence of animal parasites in naturally-contaminated sewage and irrigation water, and on vegetables irrigated with this water. A study was also made of the effect of primary sewage treatment plus chlorination on the removal of these organisms from raw sewage.

Collection of Samples

For the study of the efficiency of primary sewage treatment plus chlorination, samples were collected of raw sewage, settled sewage, and effluent of the Denver sewage plant; from the South Platte River above the sewage plant; and from the river below the plant where the effluent is discharged. Treatment at the Denver sewage plant consisted of short-period aeration followed by primary sedimentation and final chlorination of the effluent. The volume of each of the samples, in general, was 1 l. for raw sewage, 2 l. for settled sewage, 3.3 l. for effluent or the river water below the sewage plant, and 6.5 l. for the river water above the sewage plant. The locations of the sampling points are given in Figure 1.

The time of sampling was scheduled on the basis of the rate of sewage flow, so that all the samples collected on the same day would represent approximately the same water. These flow rates were established by dye studies and engineering data on the sewage plant itself.

Later, at the time the Gardeners' irrigation ditch was opened, the sampling was also extended to the gaging flume, which is 1 mi. away from the place called "river below," and to the headgate (Lammer's) near the first

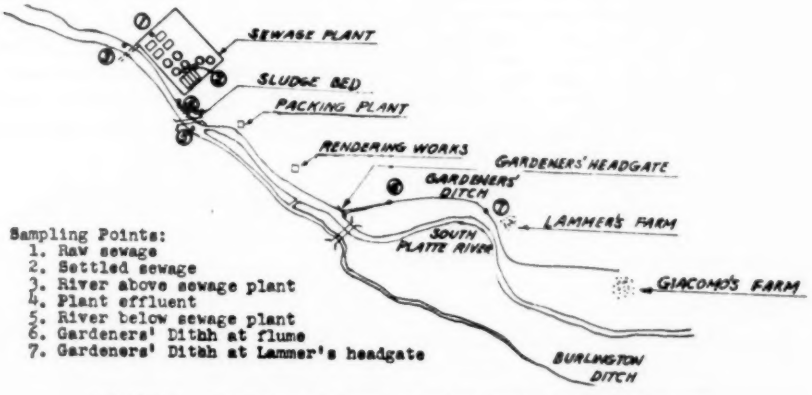

FIGURE 1.—Location of sampling points in the South Platte area.

farm, 0.5 mi. from the gaging flume. The volume of each irrigation water sample was usually 6.5 l. The locations of these sampling points are also given in Figure 1. A time schedule was likewise set, so that the samples of irrigation water would contain the same flow of the sewage as the other samples collected on the same day.

Concentration of Sediments

The efficiency of the Foerst continuous centrifuge for the concentration of helminth ova and protozoan cysts was compared with a Sedgwick-Rafter sand filter (13). Formalized suspensions of *End. histolytica* cysts and of *Ascaris* ova were used for this study. These cysts and ova were counted by the "drop count" method and the averages of six counts were recorded as the original counts. They were then added into distilled water and were recovered by both Foerst centrifuge and sand filtration methods. The ova and cysts in the sediments produced by the filter and centrifuge were also counted. Table I gives the results of five such experiments. There was little difference in the recovery of the average number of *Ascaris* ova, 81 per cent by filtration and 84 per cent with the centrifuge. A striking difference was noted, however, in the recovery of cysts. The filtration method recovered only 29 per cent, whereas the centrifuge recovered 83 per cent.

TABLE I.—Comparison of Recoveries[1] of *End. histolytica* Cysts and of *Ascaris* Ova by Sand Filtration and by Foerst Continuous Centrifuge

Experiment Number	Ova Count[2]		Cyst Count[2]	
	Filtration	Centrifuge	Filtration	Centrifuge
1	90	125	590	1,395
2	107	130	570	1,340
3	110	80	280	1,813
4	125	103	420	1,183
5	120	134	647	1,435
Average	110	114	501	1,433
Orig. counts	136	136	1,720	1,720
Recovery (%)	81	84	29	83

[1] Formalized suspensions in distilled water.
[2] Per ml. of sediment.

It was also considered that the centrifugal action of the Foerst centrifuge might affect the viability of protozoan cysts. Three control experiments were performed. A culture of *End. histolytica* was used for this study, cysts being produced by growing trophozoites in Difco's *Entamoeba* medium as modified by Chang (1) but with 2 per cent agar, and without starch, then subsequently inoculating into the same medium with starch. The results of these three experiments indicated that the action of the Foerst centrifuge apparently did not affect the viability of the cysts of *End. histolytica* to any appreciable extent when they were being centrifuged in volumes of water amounting to 3 or 6 l.

The effect of the continuous centrifuge on the viability of helminth ova was also tested using three stool specimens naturally infected with hookworm ova. The results showed that the number of hookworm ova recovered by the continuous centrifuge was about 50 to 140 per cent and most of the ova developed beyond the 8- to 16-cell stage on the next day.

From the data described, it seemed that the Foerst centrifuge had many qualifications for the study of helminth ova and protozoan cysts; therefore, it was used for all the remaining experiments during the present investigation.

Separation of Parasites from the Sediments

The concentration methods for helminth ova and protozoan cysts, as developed in the past, have all been primarily for stool specimens, which are different from the sewage-water sediment. To find the best method for

the recovery of these organisms from the sediment of sewage water, 10 experiments were conducted, using zinc sulfate centrifugal-flotation (3), the aerosol-ether-xylene method (6), direct dry film, and direct wet preparation.

Raw sewage, collected in 1-l. bottles, was centrifuged in the continuous centrifuge. The sediment was then divided into different portions, which were used in these four methods for comparison. In 10 samples of raw sewage, *Ascaris* ova and *End. coli* cysts were found most frequently. The efficiency for the recovery of helminth ova and protozoan cysts from the sediments of sewage water was compared on the basis of the number of *Ascaris* ova and *End. coli* cysts. The results showed that zinc sulfate centrifugal-flotation was the best for the recovery of *Ascaris* ova. However, it must be emphasized that in order to obtain the better recovery of *Ascaris* ova from the sediments of sewage water with $ZnSO_4$, three cover glasses were used to remove the floated materials, with 30-min. contact period between each cover glass. As for the protozoan cysts, the aerosol-ether-xylene (AEX) method appeared to be the most efficient for the recovery of *End. coli* cysts. Thus, the $ZnSO_4$ and AEX methods were both employed during the present study for the separation of parasitic materials from sediments of sewage and sewage-contaminated water.

Cultivation of *End. histolytica* and *End. coli*

For the cultivation of *End. histolytica*, sediments were inoculated into Difco's *Entamoeba* medium as modified by Chang (1) with 2 per cent agar. A few drops of bacterial flora obtained from Dr. Chang and known to be favorable for the growth of *End. histolytica* were added prior to or after the planting of the sediment. As the recovery of *End. coli* may indicate the efficiency of the sewage treatment, attempts were made also to cultivate these organisms. Tanabe and Chiba's medium (14) without added bacterial flora was used for this purpose. If growth appeared and the structure of amebae showed some resemblance to *End. histolytica* or *End. coli*, iron-hematoxylin stained smears were prepared for further identification.

Coliform and Enterococci Study

Coliform and enterococci counts were also made to correlate the findings of animal parasites. Lauryl tryptose broth as the presumptive test medium, and brilliant-green bile 2 per cent broth as the confirmatory test medium (13) were used for the coliform organisms. At least five dilutions of water sample in triplicate tubes were made for each sample.

For the isolation of enterococci, Winter and Sandholzer's media (15), as prepared by Difco, were used for presumptive and confirmatory tests of enterococci. The samples were inoculated into the presumptive broth in triplicate tubes as for coliform organisms. If a 10-ml. inoculum was used, 10 ml. of double-strength medium was used instead of 2 ml. of 5-fold strength, as recommended by Winter and Sandholzer. After an incubation period of exactly 15 hr. at 45° ± 1° C., all presumptive tubes showing acid were removed from the water bath and placed in the refrigerator for about 30 min. to allow the growth to settle. Tubes not showing acid at 15 hr. incubation were checked at 20 and 24 hr. for further change. The supernatants of the positive tubes were then poured out; a loopful of the material from the sediments of the presumptive positives was transferred to the broth portion of the slant-broth preparation, and another loopful was streaked on the slant. These tubes were then incubated at 37° C. and observed after 24 hr. for pin-point colonies on the slant surface and for growth sediment in the broth. The combination of growth of pin-

point colonies on the slants and growth sediment in the broth was interpreted as confirmed evidence for enterococci.

Viability Tests

The viability of *Ascaris* ova recovered from the samples was tested. The method was similar to, but not identical with, that used by Nolf (9) for the viability of *Ascaris* and *Trichuris* ova in feces. Changes were made to suit the sewage-water samples instead of feces. Each of the cover glasses lifted from the $ZnSO_4$ solution was examined after 1 min. by the hanging drop method. Care was taken to support the cover glasses above the slide to prevent contact of the drop with the slide.

After the positive finding was established for *Ascaris* ova, the cover glasses were placed in a 50-ml. centrifuge tube previously filled with distilled water. This tube was centrifuged for 1 min. at 1,000 r.p.m., and the supernatant was siphoned off. The small amount of sediment usually containing the ova was pipetted with a capillary pipette onto a clean cover glass ringed with balsam to prevent the drop from spreading.

The cover glass preparation was then placed in a moist chamber, drop side up, for incubation as described by Nolf (9), and then examined after an incubation period of 10 to 14 days. The ova usually developed if they were viable beyond the morula stage. The undeveloped ova were re-examined after being incubated a total period of 30 days.

The determination of the viability of *End. coli* cysts was also tried using the eosin-iodine-staining method (7). It was hoped that the results using this staining method might correlate with the culture method as described previously.

Vegetable Studies

For the vegetable sampling, whole plants were collected in sterile bags from the farms irrigated with polluted water. Between 100 and 500 g. of the edible portions were removed from 1 to 5 plants. These weighed vegetables were placed in a 1-gal. jar, into which 1 to 2 l. of sterile tap water were added. The jar was shaken vigorously 50 times, and the vegetables were then taken out with sterile forceps. The washings were run in the Foerst centrifuge.

TABLE II.—Recovery of *Ascaris* Ova and *End. histolytica* Cysts from Vegetable Washings, Using the Foerst Centrifuge and Direct Microscopic Count on the Sediment

Type of Vegetable	No. of Ova Recovered / No. of Ova Added per 2-l. Washings	Ova Recovered (%)	No. of Cysts Recovered / No. of Cysts Added per 2-l. Washings	Cysts Recovered (%)
Celery	43/48	90	375/3,416	11
Celery	500/544	92	252/2,135	12
Cabbage	1,800/1,500	120	126/1,000	12
Cabbage	1,070/1,500	71	—	—
Cabbage	1,200/1,500	80	—	—

In order to determine the recovery of helminth ova and protozoan cysts with this continuous centrifuge, five control experiments were conducted. Vegetables were placed in the jar as usual. Known quantities of formalized *Ascaris* ova and *End. histolytica* cysts were spread on the vegetables and water was added. This jar, with vegetables, cysts, ova, and water, was then shaken well and the vegetables removed. The washings were centrifuged; the sediment in the cup was washed out and made up to 10 ml. This sediment was then examined microscopically and the number of ova and cysts determined. The results are given in Table II.

The recovery of *End. histolytica* cysts (11, 12, and 12 per cent) with this method was low. However, the recovery of *Ascaris* ova showed strikingly good results, being 90 and 92 per cent from the celery, and 120, 71, and 80 per cent from the cabbage. Therefore, this method was used for the recovery of ova from the vegetables. The examination of cysts was temporarily abandoned.

After the sediments of vegetable washings were obtained, they were examined, at first with the direct microscopic method for the presence of ova. Later, the $ZnSO_4$ concentration method was used in an attempt to increase the efficiency. The AEX method was also tried and found not practical, since a considerable amount of the vegetable cells and soil materials were not extracted with ether, and these precipitated in the sediment.

Most of the sediments from vegetable washings of the early samples were preserved in 5 per cent formalin when so many samples of sewage water were collected at once, and finishing them in a short period was not possible. These sediments were examined by the direct microscopic method and later treated with NaCl centrifugal-flocculation (5). Zinc sulfate solution (sp. gr. 1.180) was found to be not suitable for the formalized samples, as reported previously by Summer (12). On the other hand concentrated NaCl solution tended to dry quickly, so that the crystals of NaCl often caused inconvenience on examination.

Effect of Primary Treatment on Removal of Parasites and Bacteria

Table III gives a summary of the incidence of *Ascaris* ova, *End. coli* cysts, coliform organisms, and enterococci in an 11-sample series of raw sewage, settled sewage, and effluent of a primary treatment plant, and of the river above and below the sewage plant. All samples were timed to approximate the rate of flow through the sewage plant and out into the river; therefore, the numbers of organisms found in these samples reflected the rate of their reduction as affected by the sewage treatment.

It will be noted in Table III that *Ascaris* ova were found in all 11 samples of raw sewage and that all 11 samples of the settled sewage also

TABLE III.—Effect of Primary Sewage Treatment on the Removal of Animal Parasites and Bacteria

Sample	*Ascaris* Ova[1]				*End. coli* Cysts[2]			Coliform (MPN/L)				Enterococci (MPN/L)			
	(no./L)	Range	Pos. Samples / No. Samples	Red. from Raw[3] (%)	(no./L)	Range	Pos. Samples / No. Samples	Red. from Raw[3] (%)	Median	Maximum	Minimum	Red. from Raw[3] (%)	Median	Maximum	Minimum	Red. from Raw[3] (%)
Raw sewage	30	5–110	11/11	—	52	20–110	11/11	—	430,000,000	110,000,000,000	39,000,000	—	23,000,000	43,000,000	4,300,000	—
Settled sewage	15	2–30	11/11	50	27	5–50	11/11	48	150,000,000	110,000,000,000	43,000,000	65	9,300,000	21,000,000	1,400,000	60
River above	1	0–1	2/11	—	1	0–1	1/11	—	43,000	110,000,000	3,600	—	230	11,000,000	36	—
Effluent	6	0–20	9/11	80	24	6–71	11/11	54	43,000	110,000,000	36	99	12,000	2,300,000	36	99
River below	6	0–14	10/11	80	8	0–17	9/11	85	3,600	2,300,000	91	99	360	230,000	73	99

[1] By $ZnSO_4$ concentration method. [2] By aerosol-ether-xylene method. [3] Average. [4] Based on median values.

showed positive for *Ascaris* ova. The river above the sewage plant was found to contain *Ascaris* ova in 2 out of 11 samples, although the number of ova was small. The effluent showed 9 positives out of 11 samples, while the river samples collected below the sewage plant showed 10 out of 11 positives.

As indicated in Table III, the reduction of *Ascaris* ova in settled sewage, as compared with the raw sewage, was 50 per cent. The number of *Ascaris* ova in the effluent showed a reduction of 80 per cent from the raw sewage. The number of ova in the water 800 ft. below the sewage plant, however, showed the same reduction of ova as the effluent.

Helminth ova other than *Ascaris* were also found in a few of these samples. Hookworm group ova were found three times in raw sewage, twice in settled sewage. The number of ova found was not great, being 10 per liter in each sample of the raw sewage and 5 and 3 in the settled sewage, respectively. There was one sample which showed hookworm ova in the raw sewage and settled sewage and which also showed 3 ova per liter in the effluent and the water sampled at the river below the plant. *Trichostrongylus* ova were also found in three samples of settled sewage and once in the effluent. The number of these ova found was low, only 5 per liter in settled sewage and 3 in the effluent. However, no *Trichostrongylus* were found in the raw sewage.

Taenea group ova were also found once in the settled sewage. The number of ova was 5 per liter, comparatively a small figure. None of this group were found in the effluent. *Trichuris* ova were also recovered once each in settled sewage and effluent, but none were found in the samples collected from the river below the sewage plant.

It must be emphasized that some of the human strains of parasitic ova are known to be morphologically indistinguishable from animal strains; hence no definite species of these ova were recorded. The criteria for positive findings thus consisted of the morphological characteristics of the human ova, although they might have originated from animals.

There was no sample which showed a cyst exactly resembling that of *End. histolytica*. Moreover, cultures of the sediments of all the samples were all negative for *End. histolytica*.

Table III also shows the recovery of cysts of *End. coli* in the samples collected from the raw sewage, settled sewage, and effluent of the Denver sewage treatment plant; and from the water of the river below and above the sewage plant. It will be noted that all 11 samples of raw sewage, settled sewage, and effluent were positive for *End. coli* cysts. The average number of cysts per liter in the raw sewage was 52, in the settled sewage, 27, and in the effluent, 24. There was a reduction of about 48 per cent from the raw sewage to the settled sewage, and 6 per cent further reduction from the settled sewage to the effluent. The number of *End. coli* escaping from this sewage treatment plant was appreciable. After the effluent left the plant, however, the number of *End. coli* cysts showed a notable reduction, the average number in the river below the plant being only 8 per liter. True, a dilution factor of 2 by the river should result in about half as many at the "river below" sampling point but, since such a reduction was not noticed in the *Ascaris* ova, it would appear some other factor was also present.

As for the removal of coliform organisms and enterococci, the results (Table III) indicated a reduction of 65 per cent for the former and 60 per cent for the latter during the sedimentation. However, the effect of chlorination on the removal of these organisms was great. A reduction of

more than 99 per cent of both organisms in the effluent was apparent. The median MPN values for these organisms of the water above the plant were comparatively low. This water diluted the effluent and the water sampled at the river below the plant is a combination of the effluent and the river water. As the amount of residual chlorine in the effluent was frequently fairly high (as much as 0.3 p.p.m.), very low median counts of coliform organisms and enterococci in the water below the plant, as indicated in Table III, could be anticipated.

Helminth Ova and Protozoan Cysts in Irrigation Water

In the samples of irrigation water, $ZnSO_4$ concentration was usually better than AEX for both ova and cysts. As shown in Table IV, 11 out of 14 samples of irrigation water from the flume of Gardeners' ditch, and 8 out of 15 samples from Lammer's headgate, the first farm on this ditch, showed positive results for *Ascaris* ova, with an average number per liter of 1.5 and 1.1, respectively. The reduction of the ova during this 1-hr. flow through the ditch appeared to be not great. It is also

TABLE IV.—Incidence of Helminth Ova and Protozoan Cysts in Gardeners' Ditch Water

Sample Number	Flume						Lammer's					
	Helminth Ova (no./l.)				*End. coli* Cysts (no./l.)		Helminth Ova (no./l.)				*End. coli* Cysts (no./l.)	
	Ascaris		Others				*Ascaris*		Others			
	A[1]	Z[2]	A[1]	Z[2]	A[1]	Z[2]	A[1]	Z[2]	A[1]	Z[2]	A[1]	Z[2]
385	3	6	0	0	9	4	0	0	0	0	4	3
388	0	1	0	0	3	3	0	1	0	0	1	0
391	6	1	0	0	9	11	6	6	1[3]	1[4]	14	23
									0	1[3]		
393	0	4	0	0	2	6	0	1	0	0	5	6
394	0	0	0	0	0	0	1	0	0	0	1	2
395	0	1	0	0	11	7	0	1	0	1[4]	1	3
									0	2[3]		
396A	0	1	0	0	0	1	0	0	0	0	0	0
396B	0	0	0	0	0	6	1	3	0	0	0	14
398A	0	1	0	0	0	1	0	0	0	0	0	0
398B	0	0	0	0	3	3	0	0	0	0	3	2
399A	0	1	0	0	0	3	0	2	0	0	0	0
399B	0	1	0	0	3	10	0	1	0	0	0	0
401	1	2	0	0	0	4	—	—	—	—	—	—
402	0	2	0	0	3	5	—	—	—	—	—	—
403	—	—	—	—	—	—	0	1	0	0	0	1
405[5]	—	—	—	—	—	—	0	0	0	0	0	0
407	—	—	—	—	—	—	0	0	0	0	0	0
Total	10	21	—	—	43	64	8	16	—	—	29	54
Average	0.71	1.5	—	—	3.0	4.7	0.53	1.1	—	—	2.0	3.6
No. Positive / Total Samples	3/14	11/14	—	—	8/14	13/14	3/15	8/15	—	—	7/15	8/15

[1] Aerosol-ether-xylene concentration method.
[2] Zinc sulfate concentration method.
[3] *Trichostrongylus.*
[4] *Hymenolepis.*
[5] Water originated from Clear Creek.

TABLE V.—Counts (MPN per Ml.) of Coliform Organisms and Enterococci in Gardeners' Ditch Water
(Sample numbers 385–407)

Count	Flume		Lammer's Headgate	
	Coliform	Enterococci	Coliform	Enterococci
Median	965	33	230	23
Maximum	110,000	930	110,000	4,300
Minimum	1	1	9	1
Ratio of Coli. to Ent.	30/1		10/1	

interesting to note that *Hymenolepis* and *Trichostrongylus* ova appeared in two samples at Lammer's headgate, but not at the flume. The possible source of these ova was investigated, since they were seldom found above Lammer's headgate. It was noted that numerous muskrats inhabit the banks of Gardeners' ditch and might have been the source of these ova of *Hymenolepis*.

The incidence of *End. coli* cysts as recorded in Table IV showed 13 out of 14 samples positive at the flume, and 8 out of 15 positive at Lammer's headgate, with an average number per liter of 4.7 and 3.6, respectively. Three samples showed more cysts at Lammer's headgate than at the flume. Of these three samples, one showed the ova of *Trichostrongylus* and *Hymenolepis* only at Lammer's headgate, and another showed higher counts of *Ascaris* ova as well as *End. coli* cysts at the headgate than at the flume.

Table V shows the coliform and enterococci counts in the Gardeners' ditch at the flume and at the first farm. The median values for coliform organisms were 965 per ml. at the flume and 230 per ml. at Lammer's headgate; for enterococci, 33 at the flume and 23 at Lammer's headgate. These figures show an increase in the density of coliforms and enterococci compared with the counts at the river below the sewage plant. The ratios of coliform organisms to enterococci were 30 to 1 at the flume and 10 to 1 at the headgate.

Correlation with Common Intestinal Organisms

As *Ascaris* ova and *End. coli* cysts were found very often in the sewage and sewage-contaminated water, it seemed worthwhile to correlate their incidence with the coliform and enterococci counts. Table VI shows the ratios of the coliform counts to the number of *Ascaris* ova, *End. coli* cysts, and enterococci in the sewage water, river water, and irrigation water. In the raw sewage, the ratios of the coliform organisms to *Ascaris* ova, *End. coli* cysts, and enterococci were 14,000,000:1; 8,000,000:1, and 19:1, respectively. In the settled sewage, these ratios were 10,000,000:1 for *Ascaris* ova, 6,000,000:1 for *End. coli* cysts, and 17:1 for enterococci. This indicates that the numbers of bacteria, either coliform organisms or enterococci, are extremely high and the numbers of animal parasites are compara-

TABLE VI.—Comparison of the Ratios of the Coliform Index to the Mean Counts of *Ascaris* Ova, *End. coli* Cysts, and Enterococci of Sewage and Irrigation Water Samples

Organism	Ratio of Coliforms to Other Organism						
	Raw Sewage	Settled Sewage	River above	Effluent	River below	Gardeners' Ditch	
						Flume	L. Hdgate
Ascaris ova	14,000,000	10,000,000	1,400,000	7,000	660	640,000	210,000
End. coli cysts	8,000,000	6,000,000	2,800,000	1,800	500	200,000	64,000
Enterococci	19	17	180	4	10	30	10

TABLE VII.—Percentages of Viable *Ascaris* Ova Recovered from the South Platte River, Denver Sewage Plant, and Gardeners' Ditch

Source of Samples	Samples Observed (no.)	Total Ova Observed (no.)	Ova Developed (no.)	Ova Not Developed (no.)	Viable Ova (%)
Raw sewage	7	23	20	3	87
Settled sewage	8	33	28	5	85
Effluent	9	25	22	3	88
River below	8	21	17	4	81
Gardeners' Ditch	10	22	19	3	86
Lammer's Headgate	8	29	24	5	83

tively very low in the raw sewage and settled sewage.

The ratios of coliform organisms to *Ascaris* ova and *End. coli* cysts in the water of the river above the sewage plant were 1,400,000 : 1 and 2,800,000 : 1, respectively. The ratio of coliform organisms to enterococci was 180 : 1.

When the sewage water became effluent, the ratios of coliform organisms to the number of *Ascaris* ova and *End. coli* cysts were 7,000 : 1 1,800 : 1, respectively. These are quite different from the ratios from the raw sewage and settled. This probably could be caused by the higher susceptibility to chlorine action of the bacteria than the animal parasites. The ratio of the coliform organisms to enterococci was 4 :1.

The counts of the river water below the plant show that the ratios of the coliform organisms to the *Ascaris* ova and *End. coli* cysts were even smaller than those of the effluent. This fact also might be contributed to the action of the residual chlorine. The ratio of the coliform organisms to enterococci at this point was 10 to 1.

When the water reached Gardeners' ditch, the ratio of the coliform organisms to the *Ascaris* ova and *End. coli* cysts rose again—640,000 :1 and 200,000 : 1 at the flume, and 210,000 : 1 and 64,000 : 1 at Lammer's headgate. The ratios of the coliform organisms to enterococci were 30 : 1 at the flume and 10 : 1 at Lammer's headgate. These higher ratios of the coliform organisms to the ova and cysts were due to the increasing number of coliform organisms, whose source is not clear. They may have multiplied, or there may have been additional contamination from the packing plant and rendering works, which discharged wastes into the river below the sewage plant.

Viability of *Ascaris* Ova and *End. coli* Cysts

Table VII shows the percentages of viable *Ascaris* ova found in all the samples studied. It will be noted from the different kinds of samples that the percentages of viable ova to the total number of *Ascaris* ova found were very similar, varying from 81 to 88 per cent. It would appear that the primary sewage treatment and chlorination did not affect the viability of *Ascaris* ova recovered, although the number of ova was markedly decreased from the raw sewage to the irrigation water.

The viability of *End. coli* cysts found in the sewage and irrigation water is not clear. The cultures were all negative. Since the media used for culture were primarily designed for the growth of *End. histolytica*, they may not be satisfactory for the detection of a few *End. coli* cysts. Negative results, therefore, may not be too significant. The eosin-stain technique on the sediments, on the other hand, suggested that most of them were viable. However, it also was found that this staining method was not reliable, since a number of eosin-resistant cysts showed obvious plasmolysis, which usually means that

the organism is dead. Therefore, the viability of *End. coli* needs further investigation.

Helminth Ova in Vegetable Washings

Vegetables collected from the farms irrigated with polluted irrigation water were studied for the presence of helminth ova. Fifteen samples, including 7 samples of celery, 4 of lettuce, and 4 of cabbage, were studied during the period the sewage plant was in operation. They were all negative for helminth ova. However, 2 out of 7 samples of vegetables, including 4 samples of celery, 2 of lettuce, and 1 of cabbage, collected during the period the sewage plant was not operating, showed *Ascaris* ova. Of these 2 positive samples, one (400 g. of lettuce) showed 2 *Ascaris* ova, whereas the other (300 g. of cabbage) revealed 1 *Ascaris* ovum.

Thirteen samples of vegetables (namely, celery, carrots, onions, cabbage, and lettuce) collected from farms irrigated with water from Clear Creek, contaminated with raw sewage from Golden, Colo., were also studied. They were all negative for helminth ova.

Discussion

The fact that animal parasites will survive after primary sewage treatment has been indicated by the experimental data of others (2)(8). Furthermore, the only effective method for the removal of animal parasites, particularly *End. histolytica* cysts, is sand filtration (2). Accordingly, it is not at all surprising that primary sewage treatment in the Denver sewage plant, even with chlorination, removed only 80 per cent of the *Ascaris* ova and 54 per cent of the *End. coli* cysts; 88 per cent of these ova in the effluent were viable. However, the viability of the cysts in the effluent is not clear. The negative culture results obtained in this work do not necessarily mean that these cysts were not viable, since the media used for the cultures were designed specifically for *End. histolytica*, and no particular medium has yet been described for *End. coli*. The eosin-stain technique, on the other hand, indicated that most of them were viable.

More than 99 per cent of the coliform organisms and enterococci were removed by the primary sewage treatment and chlorination. Since these bacteria are susceptible to chlorine, it may be concluded that the treatment used in the Denver sewage plant is probably fairly effective for the removal of the coliform organisms and enterococci.

No *End. histolytica* cysts were found in the raw or treated sewage or in the irrigation water. This fact is correlated with the low incidence of amebiasis in Colorado. However, from the data presented in this study, the occurrence of *End. coli* cysts indicated that *End. histolytica* could appear in the effluent and the irrigation water if there were any appreciable numbers in the sewage, since these two species of cysts are known to be similar.

The incidence of *Ascaris* ova and *End. coli* cysts in Gardeners' ditch was 1.5 and 4.7 per liter, respectively, at the flume; and 1.1 and 3.6 at Lammer's headgate. These ova were about 85 per cent viable. The significance of these findings is not clear, although it is considered, theoretically, that one viable ovum will become a worm in the host. While the number of viable *Ascaris* ova, approximately 1 per liter, is not particularly high, the number of liters of water running through the farms and over the fields is enormous.

The incidence of helminth ova on vegetables was very low. Only 2 out of 22 samples showed positives for *Ascaris* ova, and these were obtained at a time when the sewage plant was inoperative. This indicates that at least *Ascaris* ova could be found on vegetables if there was no sewage treatment. When the sewage plant was in operation, the 15 samples of vegetables

irrigated with this sewage-contaminated water of Gardeners' ditch showed no helminth ova. Thus, it may be suggested that, with the infiltration method used for irrigation in this area, there is minimal danger of contamination of vegetables with helminth ova from the irrigation water. However, the possibility of danger caused by the direct drinking of this water, by either human beings or animals, the contamination of shallow wells, and the hazard to children playing about the ditches, may be considerable.

Attempts were made to find or modify methods for the isolation of animal parasites in the irrigation water. The Foerst continuous centrifuge worked satisfactorily for the concentration of sediment. As for the separation of parasites from sediment, it seemed that the sediments from irrigation water varied with the seasons. When the river water level was low, the chief content of the sediment was sewage material. In this case, the zinc sulfate method showed better results for the isolation of ova, and the AEX method gave better isolation for cysts. However, when the river water level was high, the sediment contained large amounts of soil material; the AEX method then did not separate the parasites from the soil, and the zinc sulfate method was more satisfactory for the isolation of both helminth ova and protozoan cysts.

Summary

An investigation was made to determine the efficiency of primary sewage treatment plus chlorination, as practiced in the Denver sewage disposal plant, on the removal of animal parasites. The results indicated that about 20 per cent of the *Ascaris* ova and 46 per cent of the *End. coli* cysts found in the raw sewage were still present in the final effluent. The MPN of the coliform organisms and enterococci, however, showed a removal of more than 99 per cent by this sewage treatment.

When the effluent joined with the South Platte River and the flow reached Gardeners' irrigation ditch, the numbers of *Ascaris* ova and *End. coli* cysts were found to be reduced considerably. The average incidence of *Ascaris* ova per liter in Gardeners' ditch was 1.5 at the flume and 1.1 at the first farm (Lammer's); for *End. coli* cysts, the numbers were 4.7 at the flume and 3.6 at the first farm. The coliform organisms and enterococci, on the other hand, showed a higher incidence in this ditch than that of the effluent.

Helminth ova other than *Ascaris* were also found occasionally in the raw sewage, settled sewage, and effluent of the Denver sewage treatment plant and in the South Platte River below the plant. These were ova of the hookworm group, *Trichostrongylus, Trichuris,* and *Taenea.* The ova of *Hymenolepis* and *Trichostrongylus* were found twice in Gardeners' ditch at the first farm. Efforts to recover *End. histolytica* were consistently negative.

Eighty-one to 88 per cent of the *Ascaris* ova found in raw sewage, settled sewage, and effluent of the Denver sewage plant, and in the river water and Gardeners' ditch water containing the sewage effluent, were viable.

The incidence of helminth ova in vegetable washings was also investigated. One sample of lettuce and one sample of cabbage out of 7 samples of celery, lettuce, and cabbage, collected during the period the sewage plant was inoperative, showed *Ascaris* ova, whereas the 15 samples of lettuce, cabbage, and celery collected when the sewage was being treated showed negative results. Thirteen samples of celery, carrots, onions, cabbage, and lettuce collected from the Clear Creek area were all negative.

The public health significance of these findings is discussed, but definite conclusions cannot be stated since little is known of the minimum infecting doses of these organisms.

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THE OPERATOR'S CORNER

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SLUDGE DIGESTION AT OCEANSIDE, CALIFORNIA *

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Because sludge digestion at the Oceanside, Calif., sewage treatment plant had never been what was considered satisfactory, a succession of plant-scale experiments was carried out over a period of about 18 months in an effort to correct the deficiency. These experiments, consisting mostly of trials of various additives, were generally aimed at breaking up the scum layer in the digester, correcting pH, increasing gas production, and reducing odors.

Plant Description

The Oceanside plant (Figures 1 and 2) was designed to treat 2.0 m.g.d. Plant units include a comminutor, primary and secondary bio-oxidators, pre- and post-chlorinators, and primary and secondary digesters with floating covers. Sludge is vacuum filtered or hauled in liquid form for use on farms nearby. Digester gas is used in a 15-hp. water-tube boiler to generate steam for direct-injection heating of the primary digester. This last is accomplished by injecting live steam directly into the primary digester recirculation line (Figure 3) on the discharge side of the pump, which is a slow-speed, 3-hp., 4-in. unit with non-clog impeller capable of delivering 300 g.p.m. at 14-ft. head.

Both digesters are of 40-ft. diameter and 25-ft. sidewall depth. Each is equipped with high- and low-level discharge, side and bottom suction, and the primary tank has a suction line from a point 15 ft. off the bottom that can also be used as a discharge line. The secondary is equipped with a special supernatant selector. Gas facilities include the usual metering and safety accessories. Figure 4 is a flow diagram of the plant.

Early Digester and Odor Problems

The plant was put in operation in May 1950, with the digesters being filled with raw sludge to float the covers. In June, facilities for propane storage were installed to provide fuel for steam generation and the primary digester was heated to 90° F. (Later the temperature was raised to 94° to 95° F. and held there for 3½ months.) The first gas was produced on June 11. Later in the year considerable trouble was experienced with operation of the boiler, so that the long shutdown periods allowed the digester temperature to drop to 82° F. during November and December. Since early in 1951, however, the temperature has been held between 90° and 95° F.

Early in the first summer of operation pre-chlorination was started for odor control. This was deemed necessary because of the proximity of the plant to residences, the septicity of the

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FIGURE 1.—All units of Oceanside, Calif., sewage treatment plant are housed, including primary and secondary oxidators in building at left, and sludge digestion facilities at right.

sewage arriving at the plant, and the long detention periods in the oxidators. (The plant was designed for 8-hr. detention at the 2.0-m.g.d. design flow, but during 1950 the flow averaged only 0.92 m.g.d.)

Post-chlorination was also practiced for five months during the bathing season. Moreover, the percentage of total chlorine used on pre-chlorination can only be estimated, but it is thought that about 85 per cent of the 62,000 lb. used during 1950 went into the headworks. This computes to an average pre-chlorination rate of 28 p.p.m.

This information is advanced because some observers suggested that the high rate of chlorination might be causing some of the digester problem by killing some of the essential bac-

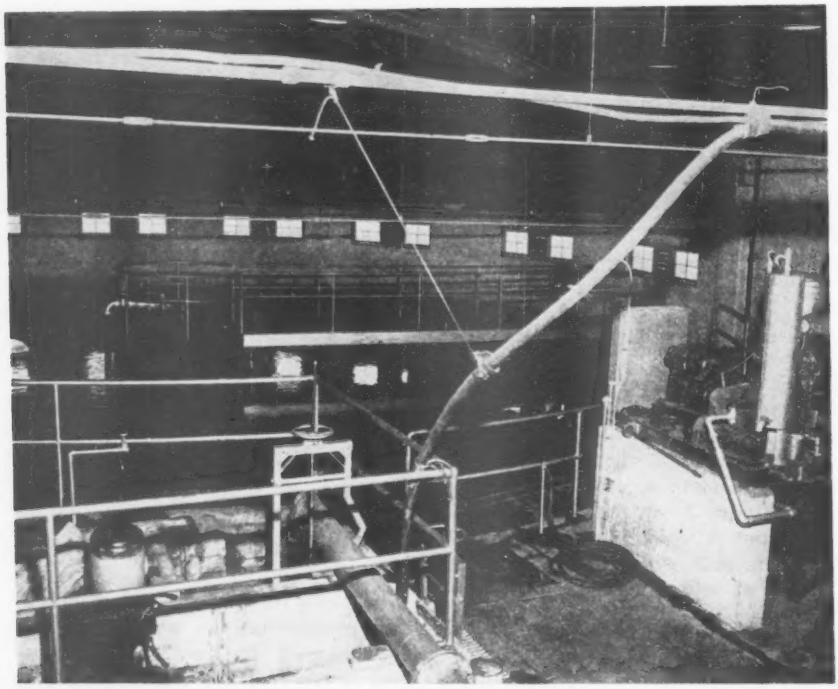

FIGURE 2.—Interior of oxidator building showing headworks (left foreground), primary oxidator (background), and part of vacuum filter (right).

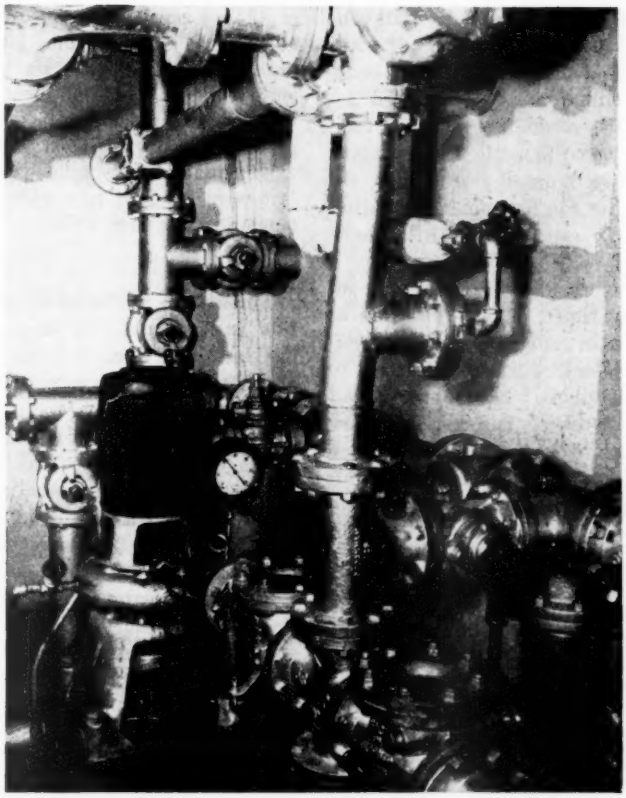

FIGURE 3.—Digester sludge recirculation pump and manifold fitted for live steam injection into pump discharge (right center).

teria in the raw sludge. In 1951, however, pre-chlorination averaged only 19 p.p.m., the decrease being attributed to greater flow and reduced septicity. In March 1952 a pump was installed to recirculate 1,100 g.p.m. of effluent to the headworks, thereby greatly reducing the odor problem, especially during the low night flows. The chlorination rate was reduced to 13 p.p.m. in 1952, but averaged 15 p.p.m. in 1953, although summer rates were much higher (25 to 30 p.p.m.).

One or two attempts to relieve the poor digestion situation early in the plant's operation were only partially successful and had only a temporary effect. Generally the digester was sour (pH 5.0 to 5.4), volatile acids were between 3,000 and 4,000 p.p.m., and the gas, although burnable, contained only 40 per cent methane. Furthermore, the gas was inadequate in quantity and it was necessary to use auxiliary fuel to heat the digester. For this latter purpose cheaper natural gas replaced the propane in March 1952.

Method of Sludge Handling

Raw sludge was and is pumped to the primary digester on a predetermined time schedule at an average of 6 min. per hour over a period of 16 hr. per day. This is subject to variation as circumstances require, in order

that the composite raw sludge will contain between 5 and 6 per cent total solids. An amount equal to the daily sludge production is transferred by pump to the secondary digester each day and allowed to settle. Supernatant is withdrawn from the secondary digester during the first shift, providing about 16 hr. settling time after each transfer.

Even though digestion has been incomplete at times, sludge is hauled in liquid form in tank trucks for spreading on farmland within a radius of 10 mi. from the plant. The sludge, spread on fallow ground before crops are planted, has proved beneficial on such vegetables as corn, spinach, and chili peppers, especially in sandy soils. No root vegetables are grown on soil treated with sludge.

Experimental Work

It was intended to empty the primary digester in the late fall of 1952 and restart it with good seed from some other plant. However, a succession of experiments during the winter of 1952–3 carried over into late spring 1953. Because of the approaching bathing season it was then too late to empty the sludge into the ocean, and there was no place else to put it as the plant has no drying beds. By fall more experiments were under way. These last were brought to a successful conclusion in January 1954.

Enzymes

The first of the latest series of digestion experiments was started in September 1952, when a total of 150 lb. of concentrated enzymes (Sea-Cal) was added to the primary digester by mixing the powdered material in the scum pit. No change resulted in sludge properties or gas production, but it was thought at that time that chromium from plating wastes was responsible for both the original failure to digest properly and the failure of the enzymes to produce any remedial effect. Analysis showed the digester scum to contain as much as 164 p.p.m. of chromium. This experiment, like all the others which followed, was performed on a "no-work-no-pay" basis.

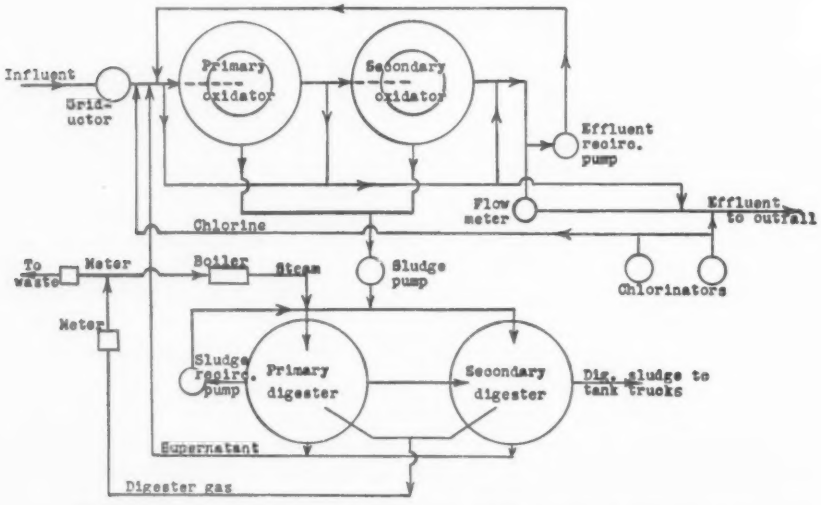

FIGURE 4.—Flow diagram of Oceanside, Calif., sewage treatment plant.

TABLE I.—Summary of Sludge Operations during Experimental Period

Month	Sewage Flow (m.g.d.)	Raw Sludge		B.O.D., 5-Day			Susp. Solids			Chlorine (lb./m.g.)	Primary Digester					Secondary Digester				Gas Prod. (1,000 c.f./day)	Chemicals Used[1] in Digester
		Prod. (g.p.d.)	Solids (%)	Infl. (p.p.m.)	Eff. (p.p.m.)	Rem. (%)	Infl. (p.p.m.)	Eff. (p.p.m.)	Rem. (%)		Temp. (°F.)	pH	Vol. Acids (p.p.m.)	Alk. (p.p.m.)	Solids (%)	Temp. (°F.)	pH	Vol. Acids (p.p.m.)	Solids (%)		
Av. 1952[2]	1.202	6,600	4.41	305	99	67.5	290	73	74.3	128	93.8	5.23	3,448	1,953	2.40	84.1	5.20	4,014	5.28	3.65	—
Jan. 1953	1.215	6,865	4.55	297	122	60.0	305	70	76.9	119	85.1	—	2,735	1,575	3.49	78.0	—	3,400	3.98	3.71	—
Feb.	1.226	6,810	4.58	336	100	70.2	326	61	81.3	117	89.6	5.41	3,350	2,050	3.10	79.0	5.34	3,740	3.28	4.01	A
Mar.	1.256	7,127	4.31	406	99	75.6	324	66	79.6	58	89.7	5.40	3,440	2,120	3.43	80.3	5.35	3,930	5.72	3.89	B
Apr.	1.324	6,955	4.46	296	91	69.9	296	60	79.7	175	89.8	5.45	3,340	2,270	3.62	82.0	5.40	3,970	3.57	4.06	C
May	1.307	7,740	4.44	299	115	61.5	315	66	79.0	154	90.2	5.38	3,610	2,850	3.38	82.5	5.32	4,238	0.67	4.94	D
June	1.344	7,916	4.55	289	95	67.0	321	58	82.0	190	90.9	5.50	3,600	2,550	2.54	84.5	5.46	4,340	5.59	4.91	—
July	1.430	6,440	5.35	—	—	—	299	71	76.2	236	92.2	5.07	3,670	2,260	4.58	86.5	5.14	4,370	2.65	4.69	—
Aug.	1.410	6,191	5.25	—	—	—	321	67	79.1	270	92.5	5.05	3,710	2,420	3.75	88.0	5.07	4,500	4.13	4.12	E
Sept.	1.356	6,147	5.30	197	61	69.0	309	65	79.0	214	91.8	5.05	3,544	2,136	3.88	86.5	5.09	4,208	2.41	4.17	F
Oct.	1.229	6,560	5.05	308	128	58.4	297	54	82.1	62[3]	91.8	5.43	4,340	2,590	5.36	86.0	5.18	4,290	4.80	5.07	G
Nov.	1.264	7,007	4.90	265	129	51.3	285	60	78.9	1.6[5]	90.4	6.32	4,760	4,240	6.74	85.0	6.09	4,830	4.94	7.38	H
Dec.	1.219	6,110	5.20	326	123	62.3	256	58	77.3	0.8[5]	91.2	6.56	4,020	4,070	4.48	83.3	6.48	3,990	5.37	7.23	I
Jan. 1954	1.260	2,070[4]	5.75	302	156	48.3	275	67	75.6	0.7[5]	92.9	6.90	2,220	3,880	3.48	82.3	6.94	2,090	3.37	17.85	—
Feb.	1.236	3,190[4]	5.71	317	119	62.4	262	62	76.3	0	93.7	7.18	1,265	4,250	1.59	78.2	7.20	385	4.22	20.66	—
Mar.	1.230	5,184	5.66	309	130	61.5	311	74	76.2	0	93.3	7.12	180	3,570	1.87	81.5	7.20	104	—	29.70	—

[1] Symbols as follows: A = 100 lb. ammonium sulfate and 95 gal. Pent-a-Vate added through scum pit; B = 300 lb. ammonium sulfate and 97 gal. Pent-a-Vate added through scum pit, plus 120 gal. Pent-a-Vate in raw sewage at headworks; C = 1,300 lb. ammonium sulfate and 38 gal. Pent-a-Vate added through scum pit; D = 1,300 lb. ammonium sulfate and 700 lb. lime added through scum pit; E = 200 lb. trisodium phosphate added through scum pit; F = 1,495 gal. "activator" added through scum pit, plus 80 gal. added to influent at headworks; G = 3,050 gal. "activator" added to primary, plus 3,900 lb. lime added through scum pit; H = 4,850 lb. lime added through scum pit; and I = 5,600 lb. lime through scum pit to primary and 450 lb. anhydrous ammonia added directly to digester circulating system.

[2] For comparison only.

[3] Chlorination of influent discontinued Oct. 8.

[4] Only part of raw sludge was pumped to the digesters.

[5] Effluent only.

Water Jets

In January 1953 an attempt was made to break up the scum layer in the primary digester by high-pressure water jets. A little progress was made, but the cover developed a tilt which allowed gas to escape around the circumference on the high side. The tilt was partially corrected by lowering the cover 2 or 3 ft.

Soil Conditioner

The next experiment involved extended use of Pent-a-Vate, a product of vegetable origin sold primarily as a soil conditioner, but for which some success was claimed in other sewage plants. From February through early April 1953, from 1 to 3 gal. of the product were added at the scum pit until a total of 230 gal. had been used. An additional 120 gal. were dripped into the influent over a period of several days. The result was a small but short-lived increase in gas production (Table I), and no other changes in the properties of the digester contents.

Ammonium Sulfate

Over the next two months 3,000 lb. of ammonium sulfate and 700 lb. of lime were added to the primary via the scum pit. This gave a small increase in gas production, up to 5,000 cu. ft. per day, and caused some of the scum to break down. Although cheaper than other ammonium compounds, the sulfate does have an adverse effect in the form of increased sulfides (50 to 60 p.p.m.) in the digester. In this case, the increased sulfides made the gas very corrosive, caused a foul odor in the sludge, and increased the sulfide content of the supernatant returned to the plant headworks. This all worked against the attempts being made at odor control, as well as consuming more chlorine.

Trisodium Phosphate

In August 1953, 200 lb. of trisodium phosphate were added to the primary digester in an attempt to break up the scum. This seemed to have no effect, however, so was discontinued.

Activator

In September 1953 an "activator" was proposed to solve the difficulty. This product is nothing more or less than supernatant liquor from a digester in which animal and vegetable waste has been completely digested. Without further preparation, 24 drums (1,300 gal.) were pumped into the primary digester at various levels. Within a few days there occurred a scum breakup of major proportions.

As a result of the scum breakup it was necessary for several days to clean the sludge circulating pump on an average of every 30 min., due to trash accumulated in the scum over a period of years. It also was necessary to shut down the sludge circulation system at night when no operator was on duty. Solids in circulation increased from practically 0 to 6 per cent, but there was little increase in gas production and only a slight increase in volatile acids.

Because it was felt that the heavy pre-chlorination might be killing off essential bacteria, a tank truck load (3,000 gal.) of the activator was added to the primary digester and pre-chlorination was discontinued at the risk of receiving odor complaints. More scum breakup and pump clogging was experienced, but there was no increase in gas production.

Lime

It was decided, therefore, to add lime to raise the pH and the alkalinity. About 200 to 300 lb. of lime were added per day, which caused volatile acids to increase to 5,500 p.p.m. The pH was raised to 6.1 by November 1. There was some increase (to 7,000 cu. ft. per day) in gas, but this later fell again to 6,300 cu. ft. per day.

In December 1953 more lime was used to raise the pH to 6.8 and hold it

there, regardless of the volatile acids. At the same time, 450 lb. of anhydrous liquefied ammonia were purchased and added to the digester by bubbling the gas into the sludge circulating pump suction at an average rate of 20 lb. per day. Altogether, 7.5 tons of hydrated lime were added to the primary digester.

On December 28 the volatile acids in the primary, which had been running around 3,900 p.p.m., started to rise sharply. Therefore, the lime and ammonia were stopped at once. The volatile acid content increased to 4,300 in two days and gas production started to increase. On the 29th, also, about 9,000 gal. of secondary digester bottom sludge were transferred to the primary.

By January 5, 1954, gas production was up to 13,000 cu. ft. per day. On that day 4,500 gal. of well-digested sludge were brought in from Camp Pendleton. This sludge contained only 50 p.p.m. volatile acids. Volatile acids in the digester then began to decrease rapidly and in a few days the pH rose of its own accord to 7.2. Gas production hit 23,000 cu. ft. per day on January 25.

Foaming developed in the primary when the gas started to increase, and a water line was rigged to keep the foam washed down. On January 15 it was necessary to stop feeding the digester to keep the foam under control. Up until then, however, the entire raw sludge production had been fed to the tank. Furthermore, foam never went over the top of the digester wall; the cover had been maintained nearly at the lowest possible level. Also, no foam got into the gas lines.

Feeding Resumed

Volatile acids reached a low of 880 p.p.m. in the primary, but in the secondary they dropped to a low of 560 p.p.m. at the bottom and 360 p.p.m. in the supernatant. After foaming subsided, about January 30, a portion of the raw sludge production was fed to the primary while gas production was still up around 19,000 cu. ft. per day. This produced an increase in volatile acids, however, so feeding was again discontinued and more bottom sludge was transferred from the secondary to the primary. Beginning February 1 an attempt was made to feed 1,200 gal. (25 per cent) of the raw sludge production to the digester each day, but this had to be discontinued after three days because of the increase in volatile acids to 1,400 p.p.m.

On February 8, feeding of small amounts was again tried, the gas production having dropped to 18,000 cu. ft. per day. This time the volatile acids did not increase, but remained at about 1,550 p.p.m. for a week. The raw feed was then gradually increased over a period of 10 days until all the raw sludge could be added to the primary digester.

Gas production began to increase on February 17 and volatile acids began to decrease. By the end of February, volatile acids were down to 620 p.p.m. in the primary and 480 p.p.m. in the secondary, with gas production at 25,000 cu. ft. per day. The gas tested 30.5 per cent carbon dioxide, 0.5 per cent oxygen, and 69.0 per cent methane (by difference).

This trend continued in March, the data showing that on March 20 the volatile acids in the primary were 100 p.p.m., in the secondary 70 p.p.m., and gas production was up to 32,000 cu. ft. per day. The raw sludge averaged 77.0 per cent volatile solids and the digested sludge in the secondary bottom 62.0 per cent volatile, indicating about 50 per cent digestion.

Odor Masking

No chlorine has been used in the headworks of the plant since October 8, 1953. There were a few odor complaints in November and December of that year, but these were eliminated by use of an odor masking compound

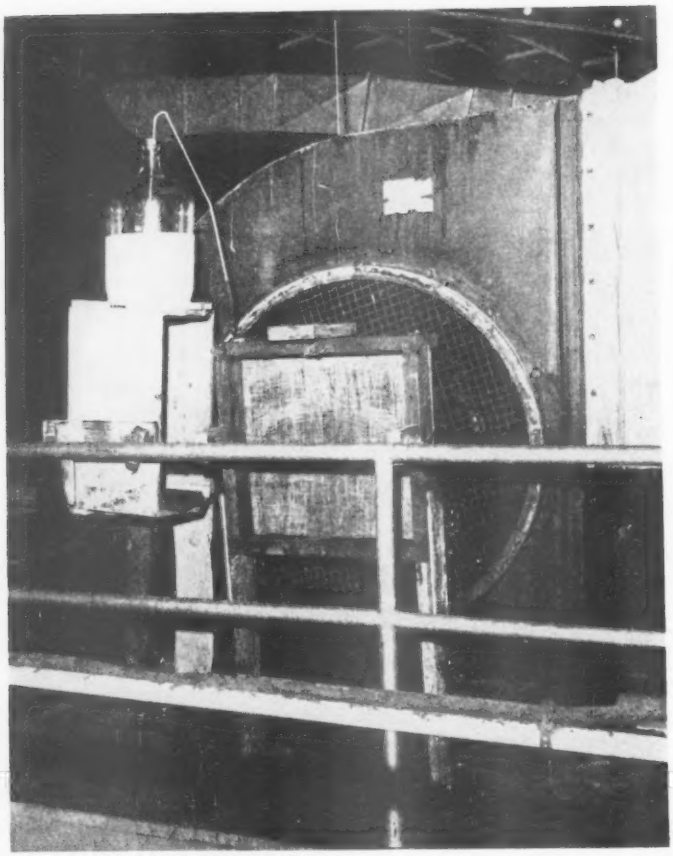

FIGURE 5.—Odor masking solution dripping on burlap stretched before ventilating blower evaporates in fan draft at rate of 1 to 1½ gal. every 8 hr.

in the ventilating system. Specifically, a wick arrangement (Figure 5) set up in front of the 14,000-c.f.m. exhaust blower evaporates the odor masking compound into the exhaust stream. This has been successful in preventing odor complaints, provided the septicity of the sewage does not go above a certain point. The product used is Neutroscent 15875*, an aromatic essential oil mixture containing chlorophyll and a wetting agent to make it miscible in water.

It may be necessary to use some chlorine in the headworks through the summer months, when the raw sewage is much more septic than in winter. It is felt, however, that if pre-chlorination does have any effect on digestion, much less chlorine will be required than has been used in the past; therefore, the effect on bacteria in the digesters will be minimized.

* Produced by Fritzsche Bros., New York, N. Y.

Savings in Costs

The saving in chlorine alone has thus far amounted to approximately 15,000 lb., or nearly $900 in value. Other than the biochemicals furnished at no cost,

the city has expended the following amounts:

3,000 lb. ammonium sulfate @ $71.92 per ton	$107.88
15,000 lb. lime, hydrated, @ $38.38 per ton	287.87
450 lb. ammonia, anhydrous, @ $0.105 per lb.	47.25
200 lb. trisodium phosphate @ $0.066 per lb.	13.20
Total	$456.20

To have dewatered and cleaned the digester would have cost about $700, plus another $300 to haul seed sludge from other plants. Including the value of the chlorine not used, the municipality has been saved about $1,440, less the negligible cost of the odor masking compound. The latter costs about $0.40 per day to operate the deodorizing system.

Acknowledgments

Grateful acknowledgment is made of the assistance and helpful advice given by Isadore Nusbaum of the California Water Pollution Control Board, Region 9. Also acknowledged with thanks is the help accorded by the suppliers of the various additives used, as follows: Ivor G. Morgan Co., Pasadena, Calif. (Sea-Cal); Pent-a-Vate Distributing Co., Anaheim, Calif. (Pent-a-Vate); and Conditioner Products Corp., Los Angeles, Calif. ("activator").

FROTHING NUISANCE AT MICHIGAN PLANT

By William J. Russell

Superintendent, Sewage Treatment Plant, Benton Harbor–St. Joseph, Mich

The new sewage treatment plant at Benton Harbor-St. Joseph, Mich., was entered into as a joint venture by the Twin Cities after a mandate from the Water Resources Commission to cease pollution of the streams into which they were discharging raw sewage. The new plant was placed in operation on July 1, 1953.

Included in the $2,144,000 total cost of the project was $86,000 for two river crossings, $88,000 for the connecting sewers, and $1,970,000 for the treatment plant. These costs include engineering fees and interest on the bonds for 18 months.

Capacity of the primary treatment unit is 8 m.g.d.; capacity of the activated sludge secondary unit is 4 m.g.d. The present flow to the plant is less than 4 m.g.d., consequently the entire flow is receiving secondary treatment.

The plant was placed in operation on a stage basis; that is, the primary unit was placed in operation on July 1, 1953, and the secondary unit on September 14, 1953. Of course there were the usual first-year bugs. Most of the difficulties have been ironed out, however, except for one thing.

Frothing a Hazardous Nuisance

The remaining problem is the enormous volume of suds (Figures 1 and 2) that at times not only covers the entire aeration area to a depth of 10 ft., but also spills out over the tank walls for a distance of some 30 ft., killing vegetation and making walks and handrails slippery and dangerous. In addition, anything more than the gentlest breeze carries the stuff to considerable distances, causing further hazard and nuisance. The billows of white have been present ever since the start of secondary treatment; sometimes only to a depth of 1 or 2 ft., but always present.

When the secondary treatment was first placed in operation a frothing problem was expected—at least until the activated sludge was conditioned

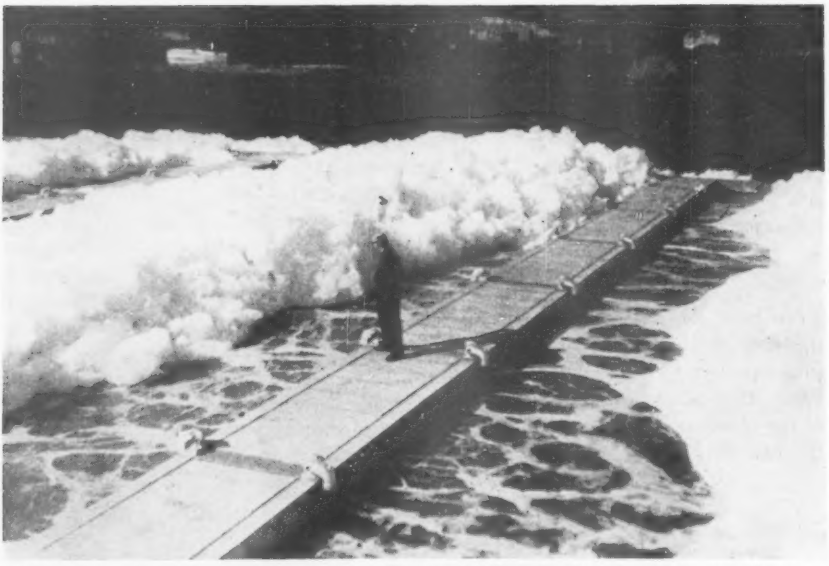

FIGURE 1.—Froth on aeration tanks at Benton Harbor-St. Joseph, Mich., constitutes a hazard as well as a nuisance.

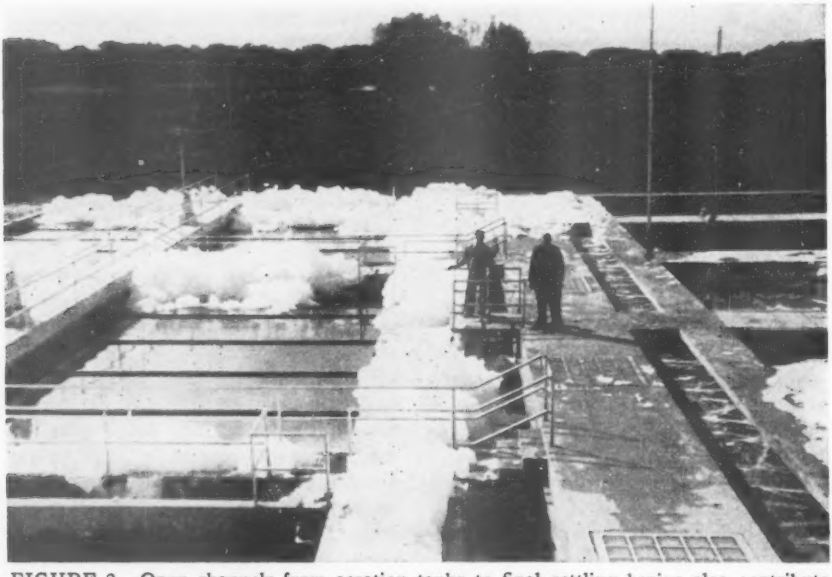

FIGURE 2.—Open channels from aeration tanks to final settling basins also contribute their share of suds.

and the solids concentration was built up to a point where it was hoped the froth could be controlled. But even when this stage was reached and passed it was still impossible to control the suds.

Raw sewage and final effluent analyses by the laboratories of the Michigan

State Health Department have shown 8.0 p.p.m. of synthetic detergent. Condensed samples of the froth itself are currently under analysis by the USPHS.

During the past few months everything that could be thought of has been tried. Search of the literature for clues, and consultation with experts for advice, has yielded only one thing —more froth. Among the several expedients tried have been variation of the mixed liquor solids concentration from 1,000 to 3,500 p.p.m., variation of the aeration tank D.O. from a trace to 3 p.p.m., and variation of the return sludge ratio from 25 to 40 per cent. All have given the same result, which is no apparent difference.

Commercial defoamants have been suggested and tried. They do the trick, but would cost about $10 per day to give effective suds control. Needless to say, that is too expensive to continue.

Spraying was tried on an experimental basis. It knocked down the froth so satisfactorily that a system is being installed to spray the surface of all aeration tanks.

Although the sudsing has been a hazard and a nuisance, it has not affected the over-all treatment process, as the plant results consistently show 90 to 94 per cent removal of B.O.D. and 94 to 97 per cent removal of suspended solids.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, Room 325, Illinois Bldg., Champaign, Ill.

Annual Report of the Oceanside, Calif., Sewage Treatment Plant for the Year 1953

By E. O. Sampson, *Foreman*

General

Although the daily average flow increased only from 1.202 m.g.d. to 1.298 m.g.d., this does not accurately reflect the situation obtaining during 1953. For example, during the first eight months of the year the flow averaged 1.314 m.g.d., but troop movements from a nearby Marine base sharply reduced the local population so that flow during the last four months averaged only 1.267 m.g.d. Population connected to the system is estimated to be about 16,000. Sewage flow remains fairly constant at about 85 g.p.c.d.

Major additions to the collection system now underway or planned for completion in 1954 will no doubt increase flow considerably, but during 1953 the plant operated at only 65 per cent of its present 2.0-m.g.d. capacity. A further contributing factor to the low flow was the low rainfall, which totaled only 4.35 in. for the entire year. (A brief description of the plant units and a flow diagram is given elsewhere in this "Corner.")

Oxidators

Until February 24, 1953, the primary oxidator was used alone as a clarifier

without aeration. Meanwhile, major changes were made in the air distribution in the secondary oxidator. The existing diffusers were removed and the diffuser manifold was raised to a point 2 ft. below the sewage surface. In place of the diffusers air jets were installed consisting of ½-in. brass valves with alternate 45° and 90° elbows on the outlets. The secondary oxidator was filled and two-stage operation using the maximum air allowable was begun on February 25. Adjustment of the air jet valves gave even distribution of air around the circle.

Even with two-stage operation and maximum aeration in the secondary oxidator little or no success was achieved in creating dissolved oxygen in the final effluent. During this period, recirculation of effluent at an average 1-to-1 ratio was in force. Although the plant was operated for two weeks in March without pre-chlorination, sulfides became so bad the chlorination of the influent was resumed for odor control. The cause of these difficulties was felt to be the prolonged retention caused by the low sewage flow and the inadequate aeration achieved by the air jets. On April 27, therefore, the secondary oxidator was by-passed and dewatered. This shutdown saved power consumption by the blowers and raised chlorine consumption only very slightly over that required by two-stage clarification. In addition, B.O.D. removal with single-stage operation was nearly as good as with two-stage operation.

One-stage clarification with continuous recirculation of effluent was maintained from April 28 to the end of the year. On November 19 the primary was by-passed for cleaning and painting. However, this in no way affected operation or the quality of the effluent, as the secondary was simply substituted for it in the flow line. In fact, the only noticeable difference was that scum had to be dipped out of the substitute tank by hand because it does not have scum collection equipment.

Several experiments were tried in an effort to gain additional aeration in the headworks. Some of these attempts were partially successful. The most favorable arrangement involved use of a sleeve around the outlet of the recirculation pump. The sleeve was 1 in. larger in diameter than the pump discharge line and was long enough to conduct the flow several feet below the influent channel surface. Thus the aspirator effect sucked air in with the recirculated liquid and gave added short-time aeration, which materially helped in reducing sulfides and their accompanying odor problem.

For the entire year, including two months of two-stage operation, suspended solids removal averaged 79.2 per cent and B.O.D. removal averaged 64.5 per cent. Solids removal was 5.0 per cent better than in 1953, which is attributed to greater use of the recirculation pump and the added aeration obtained thereby. A definite floc is now observable in the center well of the oxidator.

B.O.D. removal was down slightly from the previous year, but this was caused by returning digester supernatant to the headworks part of the time instead of discharging it to the ocean outfall. A decided increase in effluent B.O.D. occurs when supernatant is being drawn from the secondary digester and returned through the plant.

Sludge Digestion

During the year attempts were made to alleviate the sludge digestion difficulties plaguing the plant. (These experiments are described elsewhere in this "Corner.")

A period of severe clogging of the digester circulation pump by trash released from broken-up scum necessitated shutting down this pump overnight when no operator was on duty. At the same time, the raw sludge pump also was shut down all night. By this accidental means it was found unnecessary to run the sludge pump during the night, even at a reduced

rate. Therefore, this practice was established permanently in July. The result was a decrease in volume and an increase in solids concentration of the raw sludge.

Chlorination and Odor Control

Chlorine consumption amounted to 137 lb. per m.g., of which about 90 per cent was used in the influent, despite discontinuance of pre-chlorination on October 8 for the balance of the year. The increase over the 128 lb. per m.g. used in 1952 was due to the greater requirement for odor control during the exceptionally dry summer, when the influent was more septic than had previously been experienced.

As a substitute for pre-chlorination as an odor control method, an odor masking compound was aspirated into the intake of the exhaust fan in the oxidator and headworks building. (This arrangement also is described elsewhere in this "Corner.")

Sludge Disposal

An increase of 50 per cent in volume of digested sludge was given away during 1953. Obviously, the scum breakup in the primary digester released a large solids volume for shipment. All the sludge was taken by a nearby ranch in ranch equipment.

The liquid sludge has proven beneficial to the soil to which applied, despite its low pH and being only partly digested. This is because the soil itself was highly alkaline. Crops raised on this land have shown increased yields of corn and peppers; the color of spinach has been improved, but not the yield.

No charge is made for the liquid sludge, as the plant has no drying beds and the vacuum filter would be uneconomical to operate on the small volume involved.

Operating data for 1953 are summarized in Table I.

TABLE I.—Summary of 1953 Operating Data, Oceanside, Calif., Sewage Treatment Plant

Item	Average	Item	Average
Rainfall (in.)	4.35	Primary digester:	
Population, connected (est.)	16,000	Temp. (°F.)	90.4
Sewage flow (m.g.d.)	1.298	pH	5.51
Maximum (m.g.d.)	2.40	Vol. acids (p.p.m.)	3,678
Raw sludge (g.p.d.)	6,822	Alkalinity (p.p.m.)	2,592
Solids (%)	4.83	Solids (%)	4.03
B.O.D., 5-day (p.p.m.):		Secondary digester:	
Influent	302	Temp. (°F.)	83.4
Effluent	106	pH	5.45
Removal (%)	79.2	Vol. acids	4,150
Sulfides, effl. (p.p.m.)	0.39	Solids (%)	3.92
Dissolved oxygen, effl. (p.p.m.)	0.4	Supernatant drawn (m.g.)	1.713
Chlorine used:		Gas produced (1,000 c.f./day)	4.85
Pounds per day	178	Natural gas used (1,000 c.f./day)	1.41
Pounds per m.g.	137	Oper. and maint. cost ($):	
Total (lb.)	65,104	Total	22,904.50
		Per m.g.	48.22

Annual Report of the Bloom Township (Ill.) Sanitary District for the Year Ended April 30, 1953

By J. E. Meers, *Superintendent*

The present 3.5-m.g.d. activated sludge plant, put into operation in January 1937, serves a population of about 48,000 in Chicago Heights, Park Forest, and South Chicago Heights, Ill. Almost one-half of this population is in Park Forest, a new community since 1948. Most of the 60 manufacturing

establishments in or adjacent to the District are in Chicago Heights; the type of industry varies from the heaviest to the lightest.

By current standards, the design capacities of plant units are considerably reduced from the standards originally used, with the one exception of the aeration tanks. Critical lack of capacity exists in the primary settling tank, the digester, and the sludge drying beds. Less serious overload is being impressed on the final settling tank.

Plant equipment is obsolete and requires excessive maintenance and repair. Everything possible is being done to keep it in operating condition, however, pending a bond issue vote for plant enlargement and improvements. Buildings and grounds also were in poor shape, but this is being corrected by clean-up, painting, planting, and even elimination of two unsightly buildings and several old trees. An extensive program for plant rehabilitation has been outlined, to include physical, operational, and mechanical factors. Also outlined is a long-range public relations program designed to acquaint the District voters with the plant's problems and foster favorable response to an impending improvement bond vote.

Enzymes

Enzymes (Sea-Cal) were applied in the primary influent according to the following schedule: 65 lb. on October 13, 1952; 10 lb. on October 20; 6 lb. on October 27; and 6 lb. on November 3. This was an attempt to rehabilitate the receiving stream below the plant by enzyme carryover from the plant. The enzymes did not appear to do any good, although firm conclusions could not be drawn because of the lack of adequate analyses.

Digester Cleanout

Prior to tackling the major job of cleaning the 75,000-cu ft. digester and its floating cover, thorough discussions of safety measures were had with all the personnel involved. Such matters as gas explosions, dropped covers, men slipping or falling, oxygen depletion, pump actions, and the like were minutely reviewed. All tools and equipment were inspected and repaired, if needed, before the actual work was begun. Also, first aid procedures were

TABLE II.—Summary of Operating Data, Bloom Township (Ill.) Sewage Treatment Plant, Year Ended April 30, 1953

Item	Average
Rainfall (in.)	24.14
Population served, est.	48,000
Equivalent, B.O.D. basis	79,593
Sewage flow (m.g.d.)	5.2
Per capita (g.p.d.)	108.3
Suspended solids:	
Raw (p.p.m.)	449
Settled (p.p.m.)	245
Final (p.p.m.)	68
Reduction (%)	84.9
Reduction (lb./m.g.raw)	3,875
B.O.D., 5-day:	
Raw (p.p.m.)	312
Settled (p.p.m.)	147
Final (p.p.m.)	63
Reduction (%)	79.6
Reduction (lb./m.g.raw)	2,607
pH:	
Raw	7.3
Settled	7.4
Final	7.6
Sludge produced:	
Per day (gal.)	22,978
Per capita (g.p.d.)	0.479
Per m.g. sewage (gal.)	4,419
Dry solids (%)	8.9
Volatile solids (%)	38.4
Sludge solids produced, dry:	
Per day (lb.)	16,960
Per capita (lb./day)	0.353
Gas production: *	
Cu. ft. per day	24,190
Per capita (cu. ft./day)	0.504
Per m.g. sewage (cu. ft.)	4,654
Value of gas used ($)	11,785.85
Oper. and maint. costs ($):	
Total	$51,207.95
Per capita	1.067
Per m.g. treated	27.00

* On 7-month basis, due to break in recirculation line.

refreshed in memory and first aid equipment was thoroughly checked.

All this preparation paid off, with no accidents involved in the entire operation, despite the digester being out of service only six days. (It is interesting to note that shortly after this complete cleaning and checking of all the digester components this unit lost its temperature completely. The cause later was found to be leaks in the hot-water recirculation lines.)

Table II is a summary of operating data for the year.

16th Annual Report of the Oshkosh, Wis., Sewerage Commission for the Year Ending October 31, 1953 *

By R. W. Frazier, *Chief Engineer-Manager*

General

Plant buildings and equipment, together with six of the eight pumping stations, are covered by a 90 per cent co-insurance policy for property damage and extended coverage. Special types are carried for boilers, explosion, public liability, property damage, and motor vehicles. Office employees and the superintendent are bonded and the office (at the City Hall) is covered by fire, theft, burglary, public liability, and property damage policies. Compensation insurance is carried for all employees.

The Commission derives its funds from sewage service charges, as explained in a previous report.* These revenues are distributed as follows: 50 per cent for operation, 40 per cent for bond and interest redemption, and 10 per cent for depreciation. Excess funds in each account are invested in government bonds.

Equipment

A new bronze gear unit was installed in the No. 2 sludge pump and broken teeth were replaced on gears in No. 3 pump. Some piping and sludge lines were steamed out with the city steamer to loosen up the grease. The piping plugged up a number of times, but the stoppage was removed by reversing the flow and using the pressure developed by the sludge pumps. New valve seats, made locally, were installed in all the sludge pumps.

On the No. 2 gas engine the oil pump gear crystallized and several teeth broke off. Replacement with a new gear kept down-time to a minimum. Also, the exhaust manifolds were brittle, no longer fitted properly, and leaked considerably. Here, also, replacement was made. The No. 1 gas engine was not operated much, as studs and bolts broke frequently on the flywheel and in the coupling. Despite realignment and special checking, studs still were broken, so a manufacturer's mechanic is trying to find the trouble.

Pumping Stations

New exhaust piping and muffler were installed on the gasoline-driven pump at Menominee Park. As an odor control measure a 100-lb.-per-day chlorinator was installed in this same station. Dosage at about 4 p.p.m. has effectively eliminated the odor nuisance at this important recreation spot. A bomb truck (as formerly used by the Army Air Corps for transporting bombs from storage to the planes, was purchased for use in hauling ton containers of chlorine from the plant to the pumping stations. A police escort protects the movement of such units through city traffic.

Storage of the incinerator bulldozer at the plant, because of lack of space in

* For last previous extract see This Journal **25**, 4, 497 (Apr., 1953).

TABLE III.—Summary of 1952–3 Operating Data, Oshkosh, Wis., Sewerage Commission

Item	Average	Item	Average
Rainfall (in.)	26.83	pH:	
Pop. served (est.)	43,000	Raw sewage	7.7
Sewage flow (m.g.d.)	5.14	Effluent	7.7
Screenings (cu. ft./m.g.)	0.90	Raw sludge	6.4
Grit (cu. ft./m.g.)	0.65	Dig. sludge	6.9
Settleable solids:		Sludge data:	
Raw sewage (ml./l.)	4.7	Scum removal (g.p.d.)	344
Effluent (ml./l.)	0.49	Sludge removal (g.p.d.)	6,424
Reduction (%)	89.1	Solids (%)	5.2
Suspended solids:		Volatile (%)	71.5
Raw sewage (p.p.m.)	177	Dig. sludge, total (gal.)	302,500
Volatile (%)	77.9	Solids (%)	11.1
Effluent (p.p.m.)	87.4	Volatile (%)	43.9
Volatile (%)	78.3	Solids, total (dry tons)	544
Reduction (%)	46.8	Sales (dry tons)	474.45
B.O.D., 5-day:		Gas prod. (1,000 cu. ft.)	12,191.59
Raw sewage (p.p.m.)	140	(cu. ft./cap./day)	0.78
Effluent	96.3	Oper. cost ($):	
Reduction (%)	30.8	Total	52,410.12
		Per m.g.	27.91

other city facilities, has been of quite some service in that the bulldozer is available to plow our driveways and roads at the plant when heavy snowfall occurs.

Recommendations to City Council

1. Continue to set aside funds for sanitary and storm sewer separation.
2. Plan and lay out a separation program of properly designed sewers.
3. Enact an ordinance prohibiting connection of roof drains to the sanitary sewers and separate those now connected, particularly in the residential districts.
4. Plan and inaugurate a program of cleaning and repairing all sewers, manholes, and catch basins.
5. Provide a definite plan for future extensions of utilities beyond the present city limits.
6. Have all departments involved in design, construction, and maintenance of sewers coordinate activities and policies.

Table III summarizes operating data for the year ended October 31, 1953.

USE OF LUBRICATING GREASES AND OILS IN SEWAGE TREATMENT PLANTS*

By H. J. Miller

Chief Operator, Sewage Treatment Plant, Marysville, Calif.

Lubrication is one of the most important parts of operation and maintenance costs in sewage treatment plants. Therefore, any discussion of the subject should start at the point where lubricants are brought into the plant.

How should oil and grease be stored and handled? At the Marysville, Calif., plant there is a separate oil storage room in which oil drums are placed on a horizontal rack. Each drum is equipped with a valve or spigot, under which is placed a drip tray. The drip tray is important, as otherwise there would constantly be oil on the floor due to leakage or careless filling of containers.

Grease is purchased in 10-lb. con-

* Presented at 1954 Annual Meeting, California Sewage and Industrial Wastes Assn.; Sacramento, Calif.; May 5–8, 1954.

tainers, there being one container in each pumping station and one at the plant. Great care is taken to replace the container cover tightly after each use. If this were not done, dust, insects, and other dirt would enter and later get into the machine bearings.

When taking oil from the storeroom to other locations where oil is needed, 1-gal. glass jugs are used, plainly marked and with tight screw-on lids. The reason for using glass instead of metal is to be able to see any foreign material or moisture that might be in the oil, as well as to reduce waste by overflowing when filling and to be able to see how much remains in the jug.

Each gallon of oil taken from the storeroom is recorded, dated, and initialed by the operator taking it. This record sheet stays in the storeroom and gives a quick check on how much oil is left in each drum, and also how much oil should be budgeted from year to year.

Should plants have a lubricating schedule? Who should be responsible? The Marysville plant follows a schedule primarily set up by the equipment manufacturers and lubricant manufacturers. This calls for annual, semi-annual, monthly, weekly, and even daily check-ups or changes.

The solenoid or automatic oilers are filled and checked by the night operator. These oilers have glass reservoirs and are easily watched. The night operator also changes the oil in the aeration blower once a week. In this way he is held responsible for these lubricators.

Monthly check-ups are made by the day operators. They consist of removing caps to see if the oil is clean and at the correct level. Most of these reservoirs are not easily checked and should be taken care of during the day. Oil changes are made by the day operators, semi-annually from light oil in the winter to a heavier oil in the summer. Each time an oil change or check-up is made, it is recorded on daily operation sheets.

Can equipment be over-lubricated? The answer to this question, no doubt, has been experienced by many operators—bearing seals going out, bearings heating, gear boxes leaking, and many other incidents. In one case, an operator neglected to turn off an electric drive motor to check the oil level. Thinking the oil to be low, when actually it was being pumped up to a bearing, he filled it to the correct level. This motor had been operating only a few minutes before the oil was put in. After a few hours running the oil expanded—through heat—and burst the oil seal. When this happened, the oil was thrown inside on the motor windings and caused considerable damage. This type of repair is unnecessary. At the Marysville plant it has been stressed from the beginning never to over-lubricate.

Do flushing agents need to be used when changing oil in gear boxes or other reservoirs? Although flushing is not now used at the Marysville plant, if metal particles from wear should show up, flushing would be done. Recommended flushes are diesel oil or kerosene; one-half kerosene and one-half S.A.E. No. 20 motor oil is considered the best.

The problem of over-lubrication brings up the question—should a good record be kept of each piece of equipment lubricated? The answer, of course, is yes, because equipment may again be over-lubricated or, to the other extreme, under-lubricated. If a day operator, not knowing if the night operator had greased the bearing the night before, greases the bearing—only to find that it had been done—eventually the grease seal will deteriorate, making it difficult to keep the grease in until the seal is replaced. If this had been recorded and the day operator had checked the previous day's operation sheet, such a situation would not have occurred.

When a semi-annual oil change is made, say on April 20, a notation should be made on the corresponding

advance daily operation sheet (dated October 20) that the oil change is again due. This saves guess work as to the last date and having to trace back through the sheets to find it.

Can oil be re-used where there is no visible breakdown of the oil bases? Some plants do re-use their oil after it has been filtered or strained, although this has never been the policy at Marysville, where it is thought to be far cheaper to purchase a drum of oil than to have a repair bill. It is very expensive to remove a pump motor and shaft, for instance, and still more expensive to replace or align it. Also, most electric motors in sewage plants are explosion proof, and this fact makes any repair or replacement double in cost as compared to non-explosive motors.

Most lubricant manufacturers do not recommend re-using of oils. Naturally, they do not want any bad marks against their products, due to a remark that their oil caused damage to a piece of equipment when actually the oil had been re-used.

Is it possible to change from one brand of lubricants to another? Yes, as most oils and greases have the same specifications. For example, one company's No. 340 grease is the equivalent of another company's No. 20 grease. Oils, on the other hand, may vary considerably in their base material. If a change is to be made, it is wise to consult the local distributor. He has all the information on what can be used and what should not be used.

Are oil drippings and grease left on equipment harmful? Very definitely so, as these lubricants tend to soften paint and paint coverings are important in sewage plants. It is also difficult to make paint stay on where oil has been present for any length of time. Where grease and oil are left on equipment, they pick up dust, insects, and other material causing the equipment to look dirty. But the important thing is that this dirt may get into the gear boxes or lubricators when they are being checked or changed. Dirty grease will pick up heat from the sun's rays when the equipment is outside, and this heat is also damaging.

From a safety standpoint everyone knows what may happen if oil is left on the floor—someone may slip and fall and be seriously injured. This is the biggest repair bill of all and is so very unnecessary. Another point to be remembered is that oil on an uncovered but taped electrical connection may soften the insulating tape; consequently someone could be seriously burned or even electrocuted.

Lubrication in sewage treatment plants is nearly as important as any other part of the operation. Consequently, all handling, storing, usage, and cleanliness of these important maintenance supplies is also very important and should be well supervised.

TIPS AND QUIPS

"Connected," Not "Hooked"

As a public relations note, the April 1954 issue of *Splashings*, quarterly newsletter of the Kansas Sewage and Industrial Wastes Association and the Kansas Section, AWWA, points out that the next correction in sewage works terminology will be to get people to refer to houses being "connected" to a sewer and not "hooked" to it.

The inference, of course, is that nobody is "hooked" by being connected to a sewer, which should give service worth many times the amount it costs!

Portable Warning Signal

Designed for use at dangerous spots, emergency repairs, street repairs, or any other place that a portable warn-

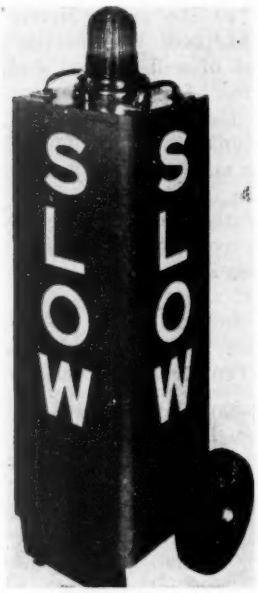

FIGURE 1.—Portable warning signal for emergency use.

ing signal may be needed, the wheel-mounted flashing amber signal light shown in Figure 1 is claimed to be so balanced that it can be moved by anyone. According to the manufacturer, General Scientific Equipment Co., 2700 W. Huntington St., Philadelphia 32, Pa., the unit is powered by a storage battery automatically recharged with a built-in charger. The unit will operate continuously for 30 hr. without outside current source and displays the word SLOW in large letters on all four sides.

How to Find A Buried Manhole

A manhole covered during a street repaving job, particularly when the metal cover and ring have been removed, can be as elusive as a will-o'-the-wisp. But a simple and effective means of snaring the "wanderer" is outlined by Superintendent Cedric Webster of the Menlo Park (Calif.) Sanitary District, as follows:

"One of our maintenance crew, Alvin McCain by name, today hit on an idea which enabled us to locate a 'lost' manhole which had managed to elude us for the past two years. His idea is the essence of simplicity and may be widely used elsewhere, but it is new to us and worked beautifully.

"A couple of years ago the County Road Department repaved one of the streets in the District's area and managed to 'lose' one of the manholes. Maps on this particular line were not of sufficient accuracy to pinpoint the manholes, and the County had neglected to tie in this particular manhole before removing the ring and cover preparatory to paving. Since the ring and cover had been removed, an electronic pipe finder was of no use. We tapped on the pavement, trying to detect a hollow sound, but with no success whatever. As there was a slight bend in the line at this lost manhole it could not be lined in. We tried inserting sewer rods in the upper and lower manholes and then picking them up with the pipe finder and projecting the indicated line with a transit; but this, too, was inconclusive.

"We could not bring ourselves to cut this newly paved street at random, even had the Road Department permitted it. It was at this point that Mr. McCain had his brain wave. His idea was to station one man inside the next manhole to listen while another man tapped with a sledge hammer on the pavement in the vicinity of the lost manhole. Sure enough, the sound of the tapping was plainly heard and it was a simple matter to pinpoint where the sound was most audible, although more than 2 ft. of fill had been placed over the lost manhole. The pinpointed spot proved to be the exact center of the elusive manhole!"

Septic Tank Cleaners

Attempts to "clean" smaller municipalities by allegedly cleaning their septic tanks and Imhoff tanks still seem to go on. This time the warning comes from Kansas, where one community was offered a contract that would have involved $1,500, but by stalling for a time the city council forced the asking price down to $700. Even that was so high, however, that the water superintendent got the sludge to draw and saved the entire cost.

This method of fleecing unwary municipal officials seems to crop up periodically and, of course, should be watched for and reported to the State Board of Health authorities.

Ill Wind

Besides making the plant an unpleasant place to work, odors from the hydrogen sulfide in the digester gas made Superintendent C. M. Allen and his Bushnell, Ill., sewage treatment plant extremely unpopular with the plant neighbors. It is hoped, however, that this unfortunate situation is in process of correction, as a gas purifier is being installed to remove the objectionable compound. As reported in *The Digester* (Feb., 1954), extreme corrosion occurred in a few years in the boiler used for digester heating and considerable replacement of parts was required. The Bushnell water supply contains approximately 650 p.p.m. of sulfates, an excellent raw material from which to build the foul smell!

Bugs with Long Reach

In an attempt to solve some of the perplexing problems with low digester activity at the Little Miami sewage treatment plant in Cincinnati, Ohio, 1,500 gal. of well-digested sludge were "imported" from the Richmond, Ind., plant. Using the Richmond plant's sludge tank truck, the 130-mi. round trip was made without mishap and in good time.

Although the results were dissapointing, the cooperation exhibited is to be commended.

Most Injuries Stem from Ten Everyday Actions

More than 85 per cent of all injuries stem from 10 everyday actions, the Institute for Safer Living reported recently after a survey of nationwide insurance statistics. The following, according to accident records, are, in order, the 10 daily actions most likely to get a person into trouble:

1. Driving or riding in an automobile.
2. Crossing the street.
3. Use of stairways. (You're comparatively safe walking up, but watch your step coming down.)
4. Walking or standing on slippery or uneven surfaces.
5. Climbing or standing on objects above ground level. (Ladders are the worst offenders.)
6. Smoking and use of matches.
7. Handling hot liquids.
8. Use of heating and cooking equipment.
9. Use of electrical appliances and equipment.
10. Handling cutting tools with sharp and pointed edges.

Alertness against accidents must not be left on the job—carry it with you wherever you go!

Federation Affairs

CINCINNATI MEETING PLANS WELL ADVANCED

Cincinnati, Ohio, will be the site of the 27th Annual Meeting of the Federation of Sewage and Industrial Wastes Associations to be held October 11–14, 1954. As the home of the Sanitary Engineering Center (formerly the Environmental Health Center) of the U. S. Public Health Service, and headquarters city of the Ohio River Valley Water Sanitation Commission, as well as being an industrial center and the proud sponsor of a comprehensive new sewage collection and treatment system now under construction for its metropolitan area, the city offers an excellent locale for the annual assemblage of all those interested in sewage, industrial wastes, and stream pollution affairs. All programmed events are scheduled to be held in the Netherland Plaza Hotel, centrally located in downtown Cincinnati.

Many local members of the host Ohio Sewage and Industrial Wastes Treatment Conference are busily at work on final details of arrangements for the meeting, which is expected to be among the largest yet held by the Federation.

Local Committees

The Local Arrangements Committee, under the general chairmanship of Arthur D. Caster, Sewage Disposal Engineer, City of Cincinnati, is composed of the chairmen of the following subcommittees:

Registration Committee: W. E. Conrad, chairman; C. E. Fisher, R. K. Horton, H. A. Lurie, J. E. Kinney, J. E. Richards, O. N. Cochran, and J. Frook.

Hotel Arrangements Committee: H. H. Mace, chairman; F. H. Dobb, S. W. Shafer, and E. P. Baker.

Finance Committee: J. M. Van Gelder, chairman; J. Crane, and D. M. Taylor.

Entertainment Committee: T. Scott, chairman; J. C. Bumstead and F. Farr, Jr.

Ladies Entertainment Committee: C. H. Allen, chairman; Mrs. A. D. Caster, Mrs. C. H. Allen, Mrs. A. B. Backherms, Mrs. D. P. Backmeyer, Mrs. J. C. Bumstead, Mrs. E. J. Cleary, Mrs. J. Crane, Mrs. F. H. Dobb, Mrs. W. G. Hamlin, Mrs. R. K. Horton, Mrs. J. E. Kinney, Mrs. H. P. Kramer, H. A. Lurie, Mrs. H. H. Mace, Mrs. V. G. MacKenzie, Mrs. T. Scott, and Mrs. D. M. Taylor.

Local Host Committee: A. B. Backherms, chairman; P. D. Haney, W. A. Moore, S. J. Ludzack, F. M. Middleton, R. C. Kroner, R. G. Snapp, R. R. Weber, and D. Enright.

Inspection Trip Committee: V. G. MacKenzie and D. P. Backmeyer, co-chairmen; H. P. Kramer, S. R. Weibel, A. E. Schwer, Jr., and H. C. Broge.

Publicity (Local) Committee: E. J. Cleary, chairman; and W. G. Hamlin.

Early Registration

To help early arrivals avoid the usual last-minute registration rush on October 11, the registration desk will be open in the Fourth Floor Foyer of the Netherland Plaza Hotel from 1 PM to 5 PM on Sunday, October 10. Pre-registration during that time is urged for all early arrivals.

Announcement to Membership

A formal announcement of the meeting was sent to all Active and Corporate Members of the constituent associations of the Federation late in June. That announcement contains further details as to technical and social programs, registration, manufacturers' exhibits, costs of the various functions, and a reservation card for hotel accommodations. It should be noted that reservations for accommodations should be made directly with the hotel.

Among the noteworthy features of the meeting program is the addition of an extra half-day session on Thursday afternoon to accommodate additional industrial waste papers. Also, a return to the earlier practice of concurrent forum sessions for operators and industrial waste personnel allows a complete afternoon for inspection trips to the new Little Miami sewage treatment plant and the new USPHS Sanitary Engineering Center.

Reviews and Abstracts*

Stabilization of Municipal Refuse by Composting. By P. H. McGaughey and H. B. Gotaas. *Proc. Amer. Soc. Civil Eng.*, **79,** Separate No. 302 (Oct., 1953).

Studies of composting in the laboratory, pilot plant, and field were made over a two-year period. Field studies were based on composting in open piles using combinations of city refuse with raw or digested sewage sludge, pear wastes, or garden soil. Tests showed seeding by several commercial preparations or manure was of no value. pH control was of little value, the shredding, moisture content, and aeration being the controlling factors. When piles are satisfactorily aerated and moistened, sufficient heat is generated and temperature can be used as an indication of the stabilization of the process.

The carbon-nitrogen ratio of the compost is important, and studies show that initial C–N ratios of 30 to 35 are optimum for rapid composting without loss of nitrogen. Turning of the pile at intervals, depending upon moisture content, was found to be the best method of aeration.

Various tables and data used in reaching these conclusions are given, and subjects covering methods of composting, judging compost quality, value of compost, and problems of municipal composting are discussed. W. A. Hasfurther

Sewage Aeration Practice in the Sanitary District of Chicago. By N. E. Anderson. *Proc. Amer. Soc. Civil Eng.*, **79,** Separate No. 310 (Oct., 1953).

Dimensions and capacities of all units at the three Chicago plants are given, with descriptions and some design data, such as ratio of diffuser area per square foot of tank area and overflow rates. Average operating data are tabulated covering one year at the Southwest plant and four years at the others.

Design criteria were based on results of experimental plants and consideration of operating data elsewhere. Primary treatment from mechanically-cleaned fine screens to Imhoff tanks has been used, with preference for settling about 30 min. Spiral-flow aeration tanks are favored and a discussion is included on the length and width of aeration tanks, their baffling, and arrangement of diffusers.

The air usage (0.35 to 0.69 cu. ft. per gallon) and the rate of sludge return vary more widely between plants than does the difference in concentration of raw sewage. Reasons for not using step aeration or reaeration of sludge, and determinations governing operating control are also discussed. W. A. Hasfurther

Composting of Garbage and Sewage Sludge. By E. Eweson. *Proc. Amer. Soc. Civil Eng.*, **79,** Separate No. 312 (Oct., 1953).

The process for manufacturing compost in a digester with four fermenting zones and one unloading zone is described. These zones are separated vertically by grids and there are facilities for injecting air at the bottom and removing excess at higher levels. The moisture, air, and carbon dioxide content of the digesting masses play an important part in the rate and completeness of digestion. With proper control finished compost can be produced in seven days. Finished compost is screened and the tailings used as culture for the fresh material.

The article briefly covers the use and layout of this compost digester, the care needed in selecting materials, and the marketing of the finished material.

W. A. Hasfurther

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

Infusoria as Indicators of Pollution in the Vistula River Below Cracow. By Lesław Turoboyski. *Gaz, Woda i Tech. Sanit.*, **27**, 326 (1953).

On the basis of a study of the infusoria present in the Vistula River below Cracow, the author submits the following conclusions: (a) There was little difference in the number of species between stations at Km. 75 and Km. 83.5, since 50 species were found at both stations; (b) the discharge of sewage from Cracow apparently had little effect on the number of species present in the stretch of river under investigation; (c) a slight change in the composition of the organisms found was noted, in that there were 9 members which could be classed as polysaprobic organisms at Km. 75 as compared with 11 at Km. 83.5, and there were 41 members classed as mesosaprobic at Km. 75 as compared with 39 at Km. 83.5; (d) using the method of Kalkowitz and Marssons, the stream may be classed as α to β mesosaprobic at Km. 75 and as α mesosaprobic at Km. 83.5; and (e) chemical analyses showed the presence of more pollution at Km. 83.5 than at Km. 75. Conrad P. Straub

Coagulation of White Water. By Jerzy Gańczarczyk and Jerzy Domański. *Gaz, Woda i Tech. Sanit.*, **27**, 329 (1953).

Most reported studies on the coagulation of white waters have been carried out at a pH of 4.5 to 4.8. Alkaline coagulation was investigated by the authors. The coagulants used were alum and lime; ferrous sulfate, $CaOCl_2$, and lime; and lime alone. Turbidity removals of about 95 per cent and permanganate O_2 demand reductions of 50 to 75 per cent are reported at alum and iron dosages of 125 to 180 mg. per l., and lime (alone) dosages of 300 to 625 mg. per l. Best results were obtained with alum at a pH of 10.2 to 10.5 following adjustment with CaO. Doubling the flocculation time from 15 to 30 min. reduced the amount of coagulant required by 17.4 per cent or increased the removal of turbidity from 60 to 87 per cent and the permanganate O_2 demand from 35 to 41 per cent in a specific instance. The presence of sulfite wastes in the white waters materially increased the coagulant requirements. Following alum treatment, the sludge contained a moisture content of 96 to 98 per cent, which could be reduced to 80 per cent in flat porous beds in the laboratory. This sludge could not be re-used in the process because of the lack of long fibers and the presence of considerable ash. In conclusion, the authors state that these studies are of a preliminary nature and will be continued to determine specific dosage requirements and conditions of coagulation. Conrad P. Straub

Sewer Capacity Design Practice. By William E. Stanley and Warren J. Kaufman. *Jour. Boston Soc. Civil Eng.*, **40**, 4, 312 (Oct., 1953).

Complete design of sewers involves three phases: (a) the determination of the flow rates of sewage; (b) the application of hydraulic science to the determination of the proper size, slope, and other characteristics of sewers; and (c) structural design of proper materials.

This article deals with only the first or "capacity design" factor. The presentation is divided into three parts: (a) capacity for sanitary sewers, (b) capacity design for storm sewers, and (c) the hydrograph method of storm sewer design. Also attached was a rather comprehensive appendix containing data relative to sewer capacity design practice in over 20 cities of the United States.

Representative data were given for each of the following factors in the capacity design of sanitary sewers: population density per capita flow, commercial flow, industrial flow disregarding liquid process wastes, and allowances for infiltration and storm water.

In designing storm sewers it was noted that a few designers still use the formula method, that most of them use the rational method, while a new method called the hydrograph method is gaining in favor. The methods of arriving at the three factors in the rational formula were discussed and modern practice summarized. It was interesting to note, in any given area, that storm sewer capacity was usually 100 times greater than sanitary sewer capacity.

The hydrograph method of storm sewer design was discussed in general terms, but details of ways of using this method are missing. Kenneth W. Cosens

Protozoal Development and Natural Purification of Flowing Sewage. By S. C.

PILLAI, G. J. M. RAO, A. J. S. PRABHAKARA, C. V. NATARAJAN, AND I. MADAPPA. *Indian Med. Gaz.*, **88**, No. 10 (1953).

The city of Bangalore, India, disposes of its untreated liquid wastes through two open channels 8 to 20 ft. wide and 4 to 24 in. deep. At a few points in the outskirts flow is diverted for land fertilizing, but the system is essentially a closed one affording excellent means for observing biochemical stabilization under natural conditions. These observations have shown remarkable clarification to be occurring over the 6-mi. course, producing a liquid chemically and biologically similar to activated sludge effluent.

Significantly, at the point of most active stabilization (3.5 mi. station) large white masses of protozoa are found. Predominantly *Epistylis* and *Carchesium* (Sp. *Vorticella*, *Paramecium*, *Stylonychia*, and *Acineta*), they cover the sides and bed of the channel for an area of approximately 1,500 sq. yd. Other forms of higher life (including rotifers, algae, larvae, and small fish) are also present. Beyond this active region, the effluent clears until at station 4.75 mi. there is no growth of protozoa and stability is complete. Laboratory aeration of samples taken at various points along the channel showed clarification to be coincident with protozoa development and indicated that their development is due to natural aeration. SUMNER KAUFMAN

Water Use and Conservation Policy. BY R. D. HOAK. *Chem. Eng. News*, **31**, 3448 (1953).

The article is a synopsis of a symposium on "Water Use and Conservation Policy" held in Los Angeles in April, 1953. It includes a discussion of the difficulties of developing a sound policy; a survey of the water resources of various regions; economics of reclamation of land; flood control; hydro-electric power; recreation; pollution control; re-use of water in industry; and irrigation water. R. S. INGOLS

Symposium on Waste Disposal in the Petroleum Industry:

1. **Taste- and Odor-Producing Components in Effluents.** BY C. C. RUCHHOFT, F. M. MIDDLETON, HARRY BRAUS, AND A. A. ROSEN. *Ind. Eng. Chem.*, **46**, 284 (1954).

The organic materials from the gravity oil separator effluents of five petroleum refineries were concentrated on carbon filters and then extracted with countercurrent liquid-liquid techniques. Aliphatic and aromatic hydrocarbons were found to produce odorous materials. Phenolic compounds were also abundant and gave rise to odors. Neutral sulfur compounds associated with aromatic materials add to the odors.

Evidence indicates that a refinery effluent should have a dilution of at least 1,000 when it is discharged into a potable water intake in order to produce a taste-free drinking water.

2. **Physical and Chemical Characteristics of Waste Water Discharges.** BY F. P. COOGAN AND E. B. PAILLE. *Ind. Eng. Chem.*, **46**, 290 (1954).

A detailed study of the various sewer streams at an oil refinery is reported. The plant discharges into a tidal estuary so that a large amount of dilution is eventually available, but the mixture of all of the wastes streams is warm enough that some sewage treatment process is necessary to maintain D. O. in the estuary.

3. **Biological Growths in Petroleum Refinery Waste Waters.** BY E. S. CROSBY, W. RUDOLFS, AND H. HEUKELEKIAN. *Ind. Eng. Chem.*, **46**, 296 (1954).

The biological slime growths in petroleum refinery waste waters were mainly of soil origin and were fed mostly by the barometric condenser water. Reduced sulfur compounds and petroleum hydrocarbons were also available as food. Marine growths were controlled by chlorine. Spent caustic wastes controlled slimes in the refinery cooling waters.

4. **Treatment of Refinery Emulsions and Chemical Wastes.** BY C. PHILLIPS. *Ind. Eng. Chem.*, **46**, 300 (1954).

The plant and experiences of the Baytown (Tex.) refinery of the Humble Oil Company are described. Calcium and magnesium soaps form emulsions that must be broken by pH control. The waste is then settled and neutralized with lime, and clarified by coagulation. The clarifier sludge is vacuum dewatered.

5. **Application of Air Flocculation to Refinery Waste Water.** BY G. A. ROHLICH. *Ind. Eng. Chem.*, **46**, 304 (1954).

A study was made of air flotation methods in removing oil from refinery waste waters. Results on waste from an API separator using air rates of 2.5, 10, and 20 cu. ft. per hr. indicated best removals with 10 cu. ft. per hr. Alum and activated silica increased oil removals by 30 per cent. These pilot plants were compared with small batch units and the results were in such agreement that the small batch units can be used for surveys.

6. Treatment of Petrochemical Wastes by Superactivated Sludge Process. By E. R. Strong and R. Hatfield. *Ind. Eng. Chem.*, **46,** 308 (1954).

The activated sludge process has been extended to accept high loading rates by using both high suspended solids and high rates of return. In pilot-plant studies loadings were maintained at 200 lb. B.O.D. per day per 1,000 cu. ft. with 99 per cent effectiveness. With loadings in excess of this value the effectiveness of B.O.D. removal dropped.

7. Biological Oxidation of Oil-Containing Waste Waters. By R. J. Austin, W. F. Meehan, and J. D. Stockham. *Ind. Eng. Chem.*, **46,** 316 (1954).

Pilot-plant trickling filters were dosed at feed rates of 8.5 to 42 m.g.a.d. As the filter loadings were increased the efficiency of a unit volume of the bed increased, although the effectiveness in removing the pollutants decreased. Recycling the effluent did not improve removal of odor or B.O.D.

8. Reclamation of Refinery Effluents. By C. D. Eaton, R. R. Evans, and F. G. Kominek. *Ind. Eng. Chem.*, **46,** 319 (1954).

The study indicates that refinery wastes can be used as make-up for recirculated cooling-water systems. However, it is doubtful whether re-use of refinery effluents can be justified in many cases because of the capital and operating costs. Where the water is urgently needed or where pollution control requirements are very strict, reclamation is technically feasible.

9. Toxicity of Various Refinery Materials to Fresh Water Fish. By H. Turnbull, J. G. DeMann and R. F. Weston. *Ind. Eng. Chem.*, **46,** 332 (1954).

Techniques for determining the median lethal dose for a given period of time indicate the degree of treatment or dilution required for a polluting waste or component of the waste. The techniques are, however, very costly. This article reports many values for specific types of refinery wastes, as well as some inorganic materials.

10. Determination of Phenols in Waste Waters by Ultraviolet Absorption. By L. J. Schnauch and H. M. Grubb. *Anal. Chem.*, **26,** 308 (1954).

A waste with oil and phenol is prepared for analysis by raising the pH to 12 and extracting the oil with carbon tetrachloride. The phenol is then concentrated in tributyl phosphate by extracting the phenol at pH 5. One portion of the tributyl phosphate extract is examined in the ultraviolet directly. The second portion is adjusted to pH 12 and the ultraviolet spectrograph obtained. A comparison of the two graphs gives good sensitivity and partial identification. There are many interferences from similar organic compounds, but not from organic nitrogenous compounds. R. S. Ingols

Pittsburgh Plans Unique Project to Abate Stream Pollution. By John F. Laboon. *Civil Eng.*, **24,** 1, 44 (1954).

The proposed project is to handle sewage and wastes from Pittsburgh and some 63 of its suburbs. Intercepting sewers will be constructed from 20 to 150 ft. below existing lines. The vertical drop shafts, up to 150 ft. deep, and the entrance structures designed to develop a spiral motion that will cause the water to cling to the manhole walls, are described. Another unusual feature is a deep intercepting sewer which will flood to a level of 74 ft. above the invert where it enters the main pump station. Reasonable velocities will be maintained and grit scouring velocities can be secured by lowering the level. Pumps are set in an annular-ring dry well around the circular wet well.

The proposed method of concentrating raw pre-heated sludge for five days, which causes it to rise so that it can be separated from the subnatant, is explained. Sludge will be conveyed by special pumps to the incinerators. W. A. Hasfurther

Improved Methods for Determining the Most Probable Number of *Bacterium coli* and of *Streptococcus faecalis*. By Eileen Childs and L. A. Allen. *Jour. Hygiene*, **51**, 4, 468 (1953).

The MPN of *Bacterium coli* and of *Streptococcus faecalis* were determined and compared by three methods. *B. coli* was grown in lactose bile salts broth and *S. faecalis* in glucose-yeast extract-azide broth. The three methods used were: (a) "Direct" method, in which the inoculated tubes were incubated directly at 44° C. for *B. coli* and 45° C. for *S. faecalis;* (b) "subculture" method, in which the primary incubation was at 37° C. for 24 to 48 hr., followed by inoculation of positive tubes to fresh media, which then were inoculated at the higher temperatures; and (c) "resuscitation" method, in which the inoculum is mixed in a part of the medium containing only sugar and peptone and incubated at 37° C. for 1 to 2 hr. to resuscitate the organisms weakened by age or by long immersion in water and the second part of the medium containing the bile salts or azide is then added to the culture and incubated at the higher temperatures.

The results showed that with samples of polluted waters the subculture method gave significantly higher counts than the direct method for *S. faecalis*, but not for *B. coli*. The resuscitation method gave significantly higher results than the subculture method for both organisms, requires less time for completion, and is specific for the organisms concerned.

H. Heukelekian

Enumeration of *Streptococcus faecalis*, with Particular Reference to Polluted Waters. By L. A. Allen, Margaret A. F. Pierce, and Hazel M. Smith. *Jour. Hygiene*, **51**, 4, 458 (1953).

Factors affecting the growth of *S. faecalis* in glucose-yeast extract-sodium azide agar were studied. High temperature of incubation (45° C.) and the pressure of azide reduced the numbers of colonies on the agar medium, the reduction being greater with cultures which had become attenuated, either through age or through prolonged immersion in water. This inhibitory action was largely overcome if the inoculum was "resuscitated" by incubating it with double-strength glucose broth before adding the azide agar portion.

Neutral red was inhibitory to some strains of *S. faecalis* and therefore had to be left out of the medium. Phosphate (0.7 per cent concentration) if autoclaved with the medium reduced the counts, so it had to be added separately to the medium. In samples with mixed population the method used permitted the growth only of *S. faecalis*. H. Heukelekian

BOOKS, REPORTS, AND PAMPHLETS

Proceedings, 26th Annual Conference. Maryland-Delaware Water and Sewage Assn., Baltimore, Md. 102 pp. (1953).

Proceedings, 16th Annual Short Course for Water and Sewage Plant Operators (1953). Eng. Exp. Sta. Bull. No. 41, Louisiana State Univ. (1954).

Report on Water Pollution in the Washington Metropolitan Area. Interstate Comm. on the Potomac River Basin, Washington, D. C. (1954).

This report consists of three separately bound sections, as follows:

Section I—Summary (7 pp.)
Section II—Technical Report.
Section III—Appendixes (figures, tables, and detailed data).

Proceedings, 35th Texas Water and Sewage Works Short School. Texas Water and Sewage Works Assn. (1953).

Besides the complete record of the meetings and papers (160 pp.), this report contains a 37-page detailed inventory of the municipal water and sewage works of Texas as of Jan. 1, 1953.

1953 Official Bulletin. Arizona Sewage and Water Works Assn. (1953).

The complete record of papers presented at the 1953 Annual Meeting of the association, Chandler, Ariz., Apr. 16–18, 1953.

Concrete Pressure Pipe Laying Instructions. Price Brothers Co., Dayton, Ohio. 16 pp. (1954).

Oxidation Ponds—Radioactivity Uptake and Algae Concentration. By E. W. Steel and E. F. Gloyna. Tech. Rep. No. 1, San. Eng. Lab., Univ. of Texas (Feb. 28, 1954).

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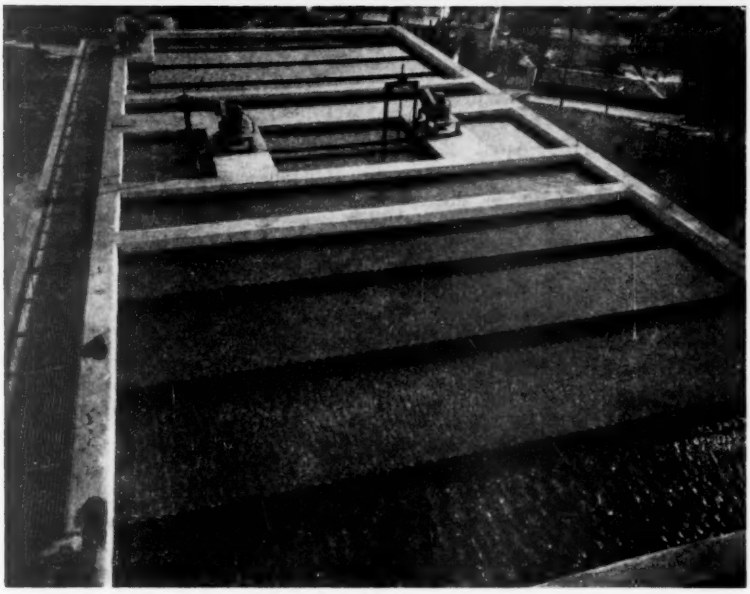

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Papers presented included the following:

"Plant Safety," by W. S. McFarland, Director of Safety, Arizona Public Service.

"Public Relations," by J. Grady, Industrial Relations, Fisher Contracting Co., Tucson.

"Sewer Maintenance Practice," by Sydney Preen, Superintendent of Sewer Maintenance, Long Beach, Calif.

"Sewer Maintenance Equipment," by A. A. Appel, Superintendent of Sewer Maintenance, Los Angeles, Calif.

"Oxidation Ponds," by B. Craun, Arizona State Dept. of Health.

A field trip was made to the Tucson water and sewage Works.

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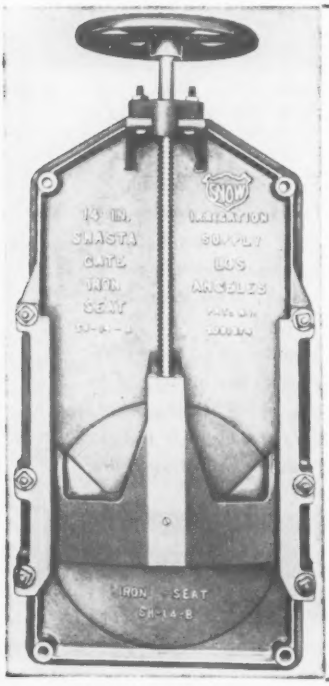

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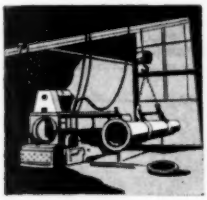

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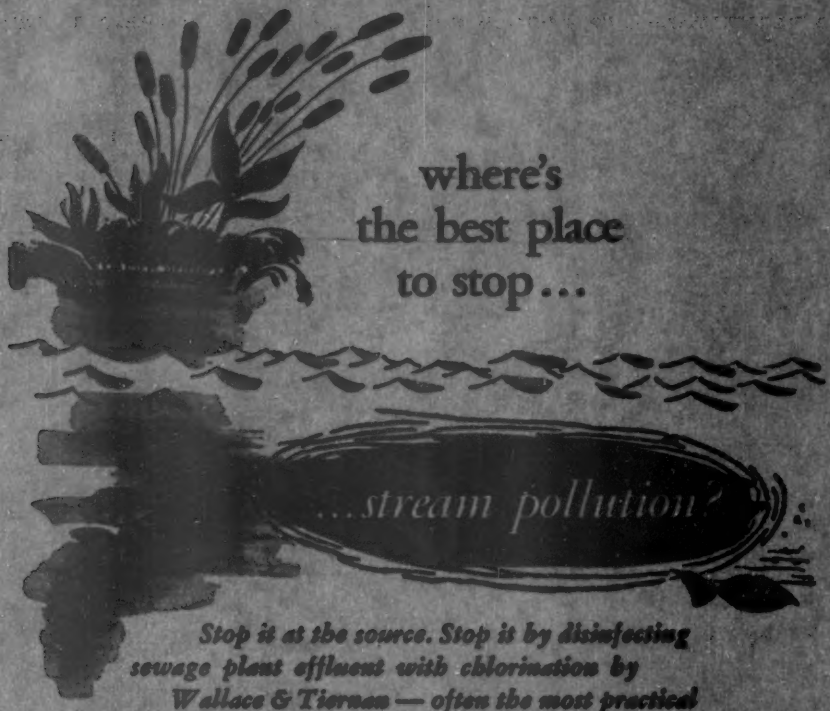

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